

FERTILIZER DEMAND


IN INDONESIA

by

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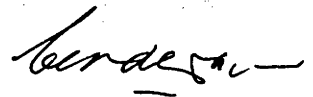
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DECLARATION

Except where otherwise indicated,
this thesis is my own work.

A handwritten signature in dark ink, appearing to read 'Bendesa', with a horizontal line underneath.

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June 1983

ABSTRACT

During Repelita I and II production of rice was a primary concern of the Government of the Indonesia because it had lagged behind consumption. To increase it existing production incentives were intensified and price incentives were adopted. Since the average fertilizer use was less than the recommended rate of 250 kg/ha (Bimas), the government tried to increase its use by manipulating the fertilizer to paddy price ratio.

The relationships between fertilizer use, and the fertilizer to paddy price ratio and irrigation were studied using secondary data from nine regions (West Java, Central Java, East Java, North Sumatra, Central Sumatra, South Sumatra, Sulawesi, Kalimantan, and Bali) for the period 1969 to 1979 (during Repelita I and II). Its policy implications were analyzed briefly.

The pooling of cross-section and time-series data technique was applied to estimate the demand for fertilizer. The demand function for Indonesia was estimated by applying a Cross-sectionally Heteroskedastic and Time-wise Autoregressive, and a Cross-sectionally Correlated and Time-wise Autoregressive models. To allow for the differences in intercept and slope accross regions a Covariance model was adopted.

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The results suggest that there was a significant difference in demand pattern across regions and the fertilizer to paddy price ratio plays a significant role in determining the demand for fertilizer. This indicates that the government should not increase the fertilizer to paddy price ratio if they wish to increase yields through increased fertilizer use. This however implies that if fertilizer is further subsidized the rich farmers who already use plenty of fertilizer will receive most benefit.

Some improvements in data used are suggested if further research is to be carried out in order to get more reliable results.

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ABBREVIATIONS AND GLOSSARY

APO	Asian Productivity Organization
AS	Ammonium sulphate
BIES	Bulletin of Indonesian Economic Studies
Bimas	(bimbingan massal) agricultural extension programme for rice and other food crops; the Bimas programme provides both credit and package of physical inputs for farmers (cf. Inmas)
BPS	(Biro Pusat Statistik) Central Bureau of Statistics
BRI	(Bank Rakyat Indonesia) the state-owned bank principally responsible for distributing agricultural credit in rural areas.
BULOG	(Badan Urusan Logistik) Logistics Board responsible for procuring and distributing various basic commodities, of which the most important is rice.
BUUD	(Badan Urusan Unit Desa) government-supported village organization established to assist in distributing farm inputs and purchasing rice and other crops; a preliminary form of a KUD (q.v.)
Bupati	Kabupaten Head
DAP	Diammonium phosphate
FRIS	Food Research Institute Studies
FAO	Food and Agriculture Organization
gabah	dry unhusked rice
HYV	high-yielding varieties (of rice and other food crops)
Inmas	(intensifikasi massal) agricultural extension programme

	for rice and food crops; the Inmas programme, in contrast to Bimas (c.q.), does not provide credit to participants but supplies them with subsidized inputs
IRRI	International Rice Research Institute
kabupaten	administrative area below the province level; average population varies from about one million in Java to less than 200,000 in parts of the Outer Islands
kecamatan	administrative area below the kabupaten (q.v.) or kotamadya (q.v.) level; average population of about 45,000 in 1979, with substantial region variation
kotamadya	municipality; having the same administrative status as a kabupaten (q.v.)
KUD	(Koperasi Unit Desa) government - supported village cooperative
Nota Keuangan	Financial Note presented with the annual Budget which provides detail of Budget proposals
NPK	Nitrogen(N), Phosphorus(P_2O_5), Potassium(K_2O)
PN	(Perusahaan Negara) state-owned enterprise
PT	(Perseroan Terbatas) limited liability company
Pusri	state-owned fertilizer company
Repelita I	First Five-Year Development Plan, 1969/70-1973/4
Repelita II	Second Five-Year Development Plan, 1974/5-1978/9
Rp	(Rupiah) national currency
Rumus Tani	Farmers' Formula
TSP	Triple superphosphate
wereng	a small grasshopper-like pest which attacks rice plants

Chapter 1

INTRODUCTION

1.1 The Problem

Food planners in Indonesia in the 1970s have viewed increased fertilizer use as the key to increasing rice production. To meet the targeted increase in domestic demand and to develop the fertilizer industry, the Indonesian government since 1968 has extended existing, and constructed new plants such as those in Aceh, East Kalimantan, Cikampek and Surabaya. Production of NPK by PT Pusri, PT Kujang and PT Petro Kimia increased at an average of 33.72 percent a year between 1967 and 1979. As a result the proportion of NPK imported fell drastically from 80 percent to only 20 percent between 1976 and 1979. In 1975 imports were greatly in excess of need because the estimates of need for the Bimas and Inmas programmes were not fulfilled (250 kg/ha). As a result production of rice tapered off between 1974 and 1976 and consumption of fertilizer decreased in 1976. Becoming aware of this situation the government decreased the price of fertilizer from Rp 80/kg to Rp 70/kg and increased floor price of gabah from Rp 65/kg to Rp 71/kg. As a consequence, both fertilizer use and production of rice increased in 1977. In the light of this situation, price incentives, floor price and ceiling price of rice, and subsidization of fertilizer may be decisive factors in resolving rice production problems. The total subsidy for fertilizer increased faster than the subsidy for food. The government is facing difficulties in financing the subsidy because of domestic budget constraints following the declining oil revenues since 1981 (Dick

1982, pp.4-6).

The subsidy on fertilizer as well as on rice was aimed at increasing production and income of the farmers. Since fertilizer is the most important factor in increasing production (Mubyarto, 1971) the government tried to increase demand for it by manipulating the fertilizer to paddy price ratio. However, there are only a few studies available concerning demand for fertilizer in Indonesia. David (1976, pp.107-120) analyzed the demand for fertilizer in Indonesia for the period of 1950 to 1972 but her result is discouraging. Rachman and Montgomery (1981, pp.239-271) estimated demand for fertilizer for the period of 1970 to 1976 only in Java and Bali. But it is quite dangerous if we analyze government policy based only on the situation in Java and ignoring the situation elsewhere because the possibilities of increasing production in the future lie mainly outside Java. A study on a broader regional front will give more reliable results.

1.2 Objective of the Study

The objectives of the study are:

To estimate demand for fertilizer for rice for the period 1969 to 1979 (during Repelita I and II) by using fertilizer to paddy price ratio and irrigation as independent variables. Besides a demand function for Indonesia, demand functions for each region will also be estimated. These regions are West Java, Central Java, East Java, North Sumatra, Central Sumatra, South Sumatra, Sulawesi, Kalimantan, and Bali. From this result we should learn whether the fertilizer to

paddy price ratio plays a significant role in influencing demand for fertilizer. Once it has been proved that the relative price is a significant factor in determining demand then the consequences for government rice policy will be briefly analyzed.

1.3 Method of Analysis

In this study, the Pooling method is applied to estimate the demand function. There are 99 observations consisting of nine regions and eleven years (1969 - 1979). In Pooling method (a) a Cross-sectionally Heteroskedastic and Time-wise Autoregressive (CHTWA), and (b) a Cross-sectionally Correlated and Time-wise Autoregressive (CCTWA) models are applied to estimate the demand function for Indonesia. The Covariance model is adopted to estimate the demand function for each region by allowing for differences in intercept and slope across regions.

1.4 Outline of the Study

In Chapter 2 the role of fertilizer in agricultural development and factors affecting the demand for fertilizer are presented in a global perspective. The general fertilizer situation in Indonesia is described in Chapter 3. Production, distribution and consumption of fertilizer are analyzed in this part. In Chapter 4 the demand for fertilizer is estimated and its policy implications are analyzed briefly. And finally in Chapter 5 a summary is presented and conclusions drawn concerning policy implications and suggestions for further research.

Chapter 2

THEORETICAL FRAMEWORK

2.1 The Role of Fertilizers in Agricultural Development

The problems of food production and particularly rice production are very closely related to the problems of fertilizer use. The success of the green revolution is largely attributed to HYVs and an increase in the use of fertilizer; hence, fertilizer use is probably the single most decisive factor for increased yields per hectare. Arnon (1981) has suggested that the combination of fertilizer and improved varieties is the sine qua non of the green revolution; therefore, for this reason the green revolution is also called the seed-fertilizer revolution.

In countries which are largely dependent upon the agricultural sector, the structure of economic development is primarily determined by sustained growth in that sector. According to the FAO (cited in Shim 1980, p.1), the single most important requirement for increasing food production in developing countries is expansion in the use of agricultural chemicals, including fertilizers and pesticides. Attention should be drawn not only to rice but also to vegetables and others crops. Timmer (1976, p.143) has emphasized that fertilizer usage is a critical determinant of food production and an understanding of the factors affecting fertilizer use on food crops is essential to an understanding of global food problems.

David (1976, p.107) has suggested that, as land is becoming scarce in South and Southeast Asia, a growing dependence is being placed upon yield per hectare to secure further output growth and

therefore upon those factors which raise yield, fertilizer, irrigation, and modern varieties. This phenomenon was also noted by Mudahar (1980, p.1) who pointed out that agricultural growth in the Asian context depends heavily upon increase in agricultural productivity resulting from land-augmenting technological change and appropriate economic incentives. Therefore the process of agricultural modernization involving the increased use of fertilizer, fertilizer responsive crop varieties and irrigation has been emphasized by Shim (1980) as follows :

'This means that if we wish to maintain the standard of living we desire, we must continue to apply fertilizers for agricultural production, because the judicious use of fertilizers has a direct and beneficial impact on all human beings thus the contribution of fertilizers is as important as irrigation water and new seeds in giving the land the high productivity which will supply more wholesome food within the limited agricultural resources available. The green revolution, which is highly dependent upon energy inputs, primarily in the form of fertilizers, pesticides and irrigation, has been followed by a big increase in rice production, which is expected to continue' (p.1).

The introduction of fertilizer responsive HYVs in a number of developing countries has created backward and forward linkages. The HYVs have been important not only in meeting food requirements of an expanding population but also in enlarging foreign exchange availability by facilitating export expansion or import substitution of agricultural commodities (Mudahar 1980, p.2). However, Evenson (1974, pp.387-94) has suggested that, even though fertilizer responsive HYVs did contribute significantly to increased production, they are by no means the sole source of productivity gains in developing countries. He was optimistic that an aggressive policy of

investment in agricultural sectors can more than offset the slowdown in the green revolution contribution due to the slowing rate of adoption of HYVs.

The Asian Development Bank (ADB, 1977) examined changes in farm output in a number of developing countries during the past decade due to the availability of irrigation and of mechanical technologies. The contribution of irrigation and fertilizer to growth in rice output was estimated for selected countries of South and Southeast Asia (Table 2.1).

Table 2.1

Estimated Proportion of Growth in Rice Production Attributed to Area and Yield for Selected Developing Countries.

Country	Period	Annual of Produc tion Growth (%)	Proportion of Total Increased Production(%)					
			Attributed to Area			Attributed to Yield		
			Irri gated Land	Rainfed and Upland	Total	Fertil izer	Residu al	Total
Burma	65-73	0.8	35.8	-23.3	12.5	47.8	39.7	87.5
India	65-70	3.2	19.2	5.8	25.0	47.3	27.7	75.0
Indonesia	65-72	4.8	46.4	- 6.8	39.6	25.2	35.2	60.4
Philippines	65-73	3.4	33.1	- 7.7	25.4	44.5	30.1	74.6
Sri Lanka	60-68	4.8	34.7	11.1	45.8	31.9	22.3	54.2
Thailand	65-72	2.1	10.8	82.2	93.0	13.6	-6.6	7.0

- a) growth is measured between five year averages centered on the years shown.
- b) one additional kilogram of N,P, or K is assumed to produce 10 kilograms of paddy.
- c) assumed to be due largely to the change in the proportion of land irrigated.

Source : ADB, 1977, p.75

In the case of area, changes were observed in irrigated land, and rainfed and upland, and in the case of yield the contribution of fertilizer was estimated. They assumed a 'rule of thumb' that an additional kilogram of NPK yields 10 kilograms of paddy. The residual contribution to yield is regarded as largely due to the improved quality of land through irrigation.

The above table shows that contribution of yields to growth in output is very high except in Thailand the growth is primarily attributable to the expansion of rainfed paddy area.

The FAO (cited in Timmer 1976, p.145) has reported that on the basis of data from 385 samples in 20 countries, a linear response function showed a 12-13 kg increase in paddy production for every kg increase in nitrogen. This figure is close to ADB's estimation. Yield response to applied fertilizer was also computed by IRRI (David and Barker, 1978). On an experimental station, responses based on data from 1968-75 showed that the yield maximum for MV (Modern Varieties) paddy ranged from 4.4 ton per hectare to 5.6 ton per hectare in the wet season. The fertilizer nitrogen required to obtain these maximum yields of MV is about 66 to 91 kg.

The same study was also carried out in Asian countries by observing the effect of harvested area and fertilizer consumption on production of rice (David and Barker, 1978; Timmer 1976, pp.143-155). Those countries are Japan, South Korea, Taiwan, (West) Malaysia, Sri Lanka, Indonesia, Thailand, Philippines, Burma, India, and Pakistan-Bangladesh. By using a Cobb-Douglas production function, a macro function was estimated based on national aggregate data. David and Barker found a high correlation between area harvested, fertilizer

consumption and production of rice. In the long term environment the yield response to fertilizer is 0.143, that is a 10 percent increase in fertilizer application would increase rice production by 1.43 percent with the same area harvested. The short term response is 0.073, about half of the long term response. This means that in the long run yield response to fertilizer will be twice the short term response.

Hayami (1964, pp.766-779) tried to explain the increase in fertilizer input in Japanese agriculture during the period 1883-1937 in terms of the shifts in agriculture's production function which is specified as a relation between fertilizer input and agricultural output, and the decline in the fertilizer price relative to the price of farm products. From 1883-1887 to 1933-1937 per hectare input of nitrogen in the form of commercial fertilizer increased tenfold while the input of nitrogen in self-supplied fertilizer increased less than 40 percent, and overall the total input of nitrogen more than doubled. According to him, three kinds of improvement underlie productivity growth; increases in fertilizer use, development and adoption of improved seeds, and land improvement including better irrigation and drainage facilities. The substantial increases in fertilizer consumption together with improvement in seeds and land were the basis for Japanese agricultural development.

2.2 Characteristics of Countries According to Their Fertilizer Environment

The fertilizer environment is related not only to the physical conditions of a country but also to its social and economic conditions. Uexkull (1975, pp.10-14) distinguished countries into

three broad categories. The first group contains countries which fulfill all the necessary pre-conditions of fertilizer use, such as potential to produce a surplus in the agricultural sector, market stability, availability of HVs, availability of side income from non-agricultural activities, minor environmental risk, and well developed research and extension services. The common features of these countries are (a) the labor force in industry is larger than the labor force in agriculture because of a rapid expansion of the industrial sector and its percapita income, (b) the agricultural sector is very diversified, (c) farm size is uniform consisting of small farms range from 0.5 to 3 hectares, (d) infrastructure such as irrigation and drainage are well developed, (e) there is very limited potential for a further expansion of acreage, and (f) even though there is a relative shortage of natural resources, social and economic institutions such as effective landreform in the past, marketing institution and farmer's cooperatives function well. Countries that can be placed in this group are Japan, Korea and Taiwan.

The second group consists of countries where some of the pre-conditions are met, for example Malaysia, the Philippines and Indonesia. These countries are characterized by 3 distinct types of production unit in the agricultural sector : (a) small farms (0.5-5 ha), (b) small to medium size farms growing food crops and cash crops, and (c) large farms (commercial estates), (d) even though there is a relative abundance of natural resources a deficit of food grains still exists, (e) a moderate to large potential is available to expand the area under irrigation and double cropping, and (f) the industrial sector is growing but minor.

The third group consists of countries where most of necessary conditions are still missing. These countries include Thailand, Burma, Cambodia and Vietnam. They are characterized by (a) heavy dominance of small rice farms (1-5 ha), (b) people mostly employed in the agricultural sector, and a very high food-grain/cash crop ratio which provides only a small commercial market for food grains, (c) prices for agricultural products are unstable, and (d) moderate natural resources are available to expand production. Major parameters of these countries are summarized in Appendix A.2.1

2.3 Factors Affecting Demand for Fertilizer

According to the FAO (cited in Arnon 1981, p.313) most of the world's fertilizer is used in developed countries. In 1966/67 developed countries consumed 62 percent of total world fertilizer, while developing countries consumed only 1 percent and the rest was consumed by centrally planned countries, as shown in Table 2.2.

Table 2.2
Fertilizer Consumption in Developed
and Developing Countries (mt)

	1966/67		1976/77		Annual growth
	Total	%	Total	%	1966/7 to 1973/4
Developed	31.6	62	44.9	47	4.6
Developing	5.1	1	15.4	16	13.2
Centrally planned	14.4	37	34.4	37	10.1
World	51.0	100	94.6	100	7.3

Source: Arnon, I., 1981, p.313

In 1976/77 the share of consumption by developed countries had decreased to 47 percent, while the share of consumption of developing countries increased to 16 percent and the rest was consumed by centrally planned countries. In that period the greatest annual growth of fertilizer was in developing countries, about 13.2 percent between 1966/67 and 1973/74, compared to 4.6 percent in developed countries 10.1 percent in centrally planned countries. These growth rates emphasize the fact that the great potential of fertilizer was still unexploited in developing countries, and that countries with low levels of fertilizer use are developing countries. Conversely high levels of fertilizer use are found in the developed countries.

This phenomenon shows that there are some problems faced by developing countries that should be eradicated in order to increase production. Generally, fertilizer problems of recent years can be classified as follows: (a) problems related to fertilizer supply, mainly of domestic production, domestic consumption, and imports and exports, (b) problems related to fertilizer price, fertilizer subsidy and rice prices, and (c), problems related to fertilizer efficiency and stability of fertilizer response in turn associated with water control, improved crop management, and timing and placement of fertilizer application.

In the countries with low land productivity (that is, less than 2.3 mt. of paddy per hectare) basic investment or leading inputs such as irrigation, drainage, etc. are very important since they are preconditions for a substantial increase in yields per hectare (Ishikawa 1967, pp.180-184). In Japan, a productivity level of 2.3 mt had been achieved in the late Tokugawa era. Hence, in the subsequent

Meiji era attention was devoted to increasing fertilizer use by increasing rice price and developing modern credit facilities.

Timmer (1976, p.146) put forward three broad factors affecting any farmer's fertilizer use, as follows:

- a. environmental factors, especially the physical response of the crop to fertilizer.
- b. economic factors, especially the price of fertilizer relative to the price at which the crop can be sold, but also including any capital or credit constraints on how much fertilizer can be purchased.
- c. the conditions of knowledge about fertilizer, the degree of uncertainty surrounding the results of its use, and the attitude about attendant risks.

He recommends that attention should be drawn to the factors that primarily affect the farmers so the government can implement suitable policy.

Shim (1980, pp.3-11) emphasized price factors in analysing the factors affecting fertilizer use. According to him only a small portion of the area under crops in Asia is receiving the benefits of fertilizer application, due to its high price. Not only are most farmers poor, but the price is also relatively high compared with the prices they receive for grain in the market. If the price of fertilizer is relatively low compared with the price of the agricultural output, new technologies such as HYVs and chemical fertilizer, etc. which increase yields could easily be introduced to farmers and be readily accepted by them. On the other hand if the price of fertilizer exceeds the price of incremental output produced,

the amount of fertilizer used may be less than physical optimum levels, and as a consequence attainment of national food objectives may be jeopardized. He realized, however, that lower prices of fertilizer alone cannot result in substantial increases in fertilizer use as long as other production constraints remain, such as lack of irrigation and drainage facilities, unavailability of appropriate machines, lack of institutional credit, high prices for seeds, etc.

Until a decade ago in most Asian countries, fertilizer was used primarily on plantation crops such as sugarcane. In the 1970's the rates of fertilizer application in the South and Southeast Asian countries were still far below those in east Asia (Japan, Taiwan, and South Korea). Consequently the rice yields of the South and Southeast Asia were still low. David (1976, p.107) proposed that the pattern of fertilizer paddy price ratios suggests one explanation for the variation in the rate of fertilizer consumption between those countries. These patterns are shown in Table 2.3. This view is confirmed from data collected by Palacpac (1982), which shows that there was a tendency for a lower fertilizer to paddy price ratio to result in higher fertilizer use and rice yields.

The correlation coefficients obtained are high, that is -0.71 (but only -0.25 excluding Japan and Korea) between fertilizer to paddy price ratio and fertilizer use, and -0.86 between fertilizer use and rice yield.

Table 2.3

The Interaction between Real Fertilizer Price, Fertilizer Use and Rice Yields in Selected Countries 1976

Country	Fertilizer/Paddy Price ratio	Fertilizer Use (kg/ha)	Rice Yield (mt/ha)
East Asia			
Japan	0.53	365	5.30
Korea Rep.of	1.54	180	5.96
Southeast Asia			
Malaysia	2.07	56	2.70
Thailand	4.08	13	1.86
Burma	1.80	8	1.79
Philippines	3.52	30	1.82
South Asia			
Pakistan	3.78	41	2.35
Srilanka	1.68	49	1.79
India	3.80	35	1.63

Fertilizer refers to NPK

Source : Palacpac, A.C., 1982

Two extreme figures can be compared between Japan and Thailand. In Thailand the fertilizer to paddy price ratio is about 8 times higher than in Japan while its fertilizer use is about 28 times lower than Japan and its rice yield is 2.8 times lower than Japan. In Burma where the fertilizer to paddy price ratio is relatively low compared with other Southeast Asian countries the fertilizer use remains low. Probably this is caused by government intervention in the distribution of fertilizer.

Factors affecting demand for fertilizer have been analyzed quantitatively by many authors. In India, Parikh (1965, pp.1-19) tried to identify and measure the quantitative significance of the factors that were responsible for a rapid growth in consumption of fertilizer during the period 1951-1961. Factors observed were irrigation, the prices paid for nitrogenous fertilizer in relation to prices received by the farmers for the product, and extension of knowledge among farmers about the use of fertilizer by using time series trend as proxy. Nine states were studied. This study reveals that between 81 to 96 percent of the nitrogenous consumption was explained by relative prices of nitrogen to product, irrigation and knowledge.

Heady and Yeh (1959, pp.332-348) examined the demand for fertilizer in the USA for period 1910-1956. Based on time series data, a Cobb-Douglas production function was fitted to estimate demand elasticities for fertilizer price and other relevant variables. They concluded that besides a decline in the fertilizer/crop price ratio, non economic factors were important in explaining the increased consumption of fertilizer. The mean elasticity of coefficient for fertilizer/crop prices were -0.49 to -1.71. This coefficient would indicate that on the average if fertilizer /crop prices decrease by 1 percent 'ceteris paribus', the quantity of fertilizer used by farmers can be predicted to increase by 0.49 percent to 1.71 percent.

The same study was carried out by Hsu (1972, pp.299-309) in the case of Taiwan during 1950-1966. The estimation of the demand function for nitrogen phosphate and potash was based on time series data. The variables affecting fertilizer use were the official

relative price of fertilizer to rice, lagged yields of rice (one year) and time. The elasticity relative price of nitrogen ranged from -0.43 to -0.55. According to him, this figure suggests that in encouraging the peasants to increase the use of nitrogen to raise agricultural productivity the price incentive must be effectively utilized.

Hayami (1964, pp.766-779) estimated demand for fertilizer in Japan over the period 1883-1937. He found that the coefficient of fertilizer price to farm products price was about -0.73 to -0.60, implying a decline over time in the relative price of fertilizer with a consequent increase in fertilizer use. Over the period 1883-1937, 70 percent of the increase in the use of commercial fertilizer is explained by technical progress in agriculture which resulted in a continuous shift of the fertilizer demand schedule and the remaining 30 percent is explained by technical progress in the fertilizer industry which lowered the price of fertilizer relative to the price of farm products. He concluded that government policy to encourage agricultural research and extension to improve water control caused shifts in the agricultural production function which stimulated the use of fertilizers. He observed that the decline in fertilizer prices relative to the prices of farm products resulting from technical progress in the fertilizer industry helped in increasing fertilizer consumption in Japan.

David (1976, pp.107-123) tried to estimate the demand for fertilizer based on aggregate Asian data over the period 1950-72. The price elasticity was derived from the relation between fertilizer use per hectare and the fertilizer rice price ratio. From the demand function she found the following price elasticities of demand: Japan,

-0.723; South Korea, -0.931; Taiwan, -0.968; Sri Lanka, -0.818; Philippines, -0.492; India, -1.671, Indonesia, -0.186. However according to Rachman and Montgomery (1980, pp.239-271) the results obtained by David for Indonesia were not very satisfactory. They argued that demand elasticities for fertilizer in Indonesia should at least approach the estimate for the Philippines or Sri Lanka which are island countries with similar climates, topography, etc. According to them there are two reasons underlying David's unsatisfactory result, namely, misspecification of model and the data used. David's time series data (1950-72) were based on the FAO data. They suggested that more accurate data were available at the Agricultural Institute in Bogor. In addition, there was political unrest between 1950's and 1960's which resulted in difficulties in collecting data. Also, major improvements have been made by the Central Bureau of Statistics in collecting and processing data since 1970. Therefore they suggest that fertilizer demand should be based on time series beginning only in 1970.

Rachman and Montgomery (1980, pp.239-271) tried to modify David's model. The data consist of six years biannual (1970-76) observations for the four provinces of Java plus Bali. They found that the price elasticity of demand ranged from -0.576 to -1.128. They came to the conclusion that a real fall in the price of fertilizer may stimulate the use of more fertilizer use per hectare.

Chapter 3

THE FERTILIZER SITUATION IN INDONESIA

3.1 Production of Fertilizer

Domestic production of chemical fertilizer is a monopoly of the Government of Indonesia. As a part of the government import substitution policy, new plants have been built and the capacity of fertilizer production has continued to increase. PT Pusri was established in 1963 with a capacity of 100,000 mt of urea a year.

Table 3.1

Existing Plants and Capacity

	Fertilizer	Plants	Capacity	Product	Location
		mt/year			
1	PT Pusri I	100,000	Urea	Palembang	
2	PT Pusri II	380,000	Urea	Palembang	
3	PT Pusri III	570,000	Urea	Palembang	
4	PT Pusri IV	570,000	Urea	Palembang	
	Total PT Pusri	1,620,000			
5	PT Petro Kimia	45,000	Urea	Gresik	
		150,000	AS	Gresik	
		530,000	TSP	Gresik	
		80,000	DAP	Gresik	
6	PT Pupuk Kujang	570,000	Urea	Cikampek	
7	East Kalimantan	570,000	Urea	Kalimantan	
		165,000	Ammonia	Kalimantan	
8	Aceh				
	(ASEAN Project)	570,000	Urea	Aceh	

Source : Mulyono, B., 1979, p.81

In the following 10 years PT Pusri plants were expanded. PT Pusri II became operational in 1974, PT Pusri III in 1976 and PT Pusri IV in 1977 with rated capacities of 380,000, 570,000 and 570,000 mt of urea respectively, as shown in Table 3.1.

The cost of PT Pusri III was estimated at \$ 192 millions and was partially financed by an IBRD loan of \$ 115 millions and PT Pusri IV was financed at an estimated cost \$ 186 millions with loans from IBRD and Saudi Arabia (Slayton and Exawirya 1978, pp.70-84).

Another plant, PT Petro Kimia (Gresik), was completed in 1972 with capacity of 45,000 mt of urea and 150,000 mt of ammonium sulphate a year. In 1978/79 PT Petro Kimia was expanded to a capacity of 530,000 mt of TSP, and 80,000 mt of DAP. These new plants were built in an attempt to overcome the shortage of fertilizer supplies caused by the oil crisis in 1973. A new plant, PT Kujang (Cikampek - West Java), was completed in 1978 with capacity of 570,000 mt of urea at an estimated project cost of \$ 256 millions. The East Kalimantan plant was established in 1981 and was expected to begin operation in 1982 with capacity of 570,000 mt of urea and 165,000 mt of ammonia a year. The cost of this project was estimated at \$ 500 million. The ASEAN Aceh urea plant, on which construction began in 1978, was commercially operational in 1981 with a capacity of 570,000 mt of urea a year.

For production of NPK PT Pusri produced 100 percent of N (Nitrogen) between 1967 and 1971 and an average 81 percent between 1972 and 1979. PT Kujang produced 5 percent (33,076 mt) of N in 1978 and 24 percent (438,806 mt) in 1979. Production of NPK increased at an average of 33.72 percent (Table 3.2) between 1967 and 1979.

Table 3.2
Domestic Production of NPK
(mt)

Year	N				Total N	P	K	Total
	Pusri	%	Kujang	P.Kimia				NPK
1	2	3=2:6	4	5	6=2+4+5	7	8	9=6+7+8
1967	42,935	100			42,935	546		43,481
1968	43,943	100	-	-	43,943	376	-	44,319
1969	38,718	100	-	-	38,718	850	-	39,568
1970	45,267	100	-	-	45,267	302	-	45,569
1971	48,185	100	-	-	48,185	44	-	48,229
1972	49,782	83	-	10,083	59,865	234	-	60,099
1973	49,803	61	-	31,671	81,474	309	-	81,783
1974	87,890	73	-	32,936	120,826	1,225	-	122,051
1975	176,536	85	-	31,002	207,538	1,570	-	209,108
1976	168,035	91	-	16,149	184,184	1,209	-	185,393
1977	371,018	94	-	25,131	396,149	497	-	396,646
1978	627,455	90	33,076	33,512	694,043	714	-	694,757
1979	632,913	73	201,801	33,801	868,565	56,696	1,272	926,533
Average of Annual Rate Growth 1967 - 79								33.72%
1967 - 76								20.20%
1976 - 79								74.20%

Source : Direktorat Bina Sarana Usaha Tanaman Pangan, 1977 and 1979

Domestic production of NPK increased rapidly after PT Pusri III, PT Pusri IV, PT Pupuk Kujang and PT Petro Kimia were operational. Between 1976 and 1979 production increased 74.2 percent annually as compared with only about 20.2 percent a year between 1967 and 1976.

3.2 Consumption, Import and Supply of Fertilizer

Urea accounts for two-thirds of fertilizer applied in Indonesia, and represented 68 percent of total nitrogen (N) production between 1967 and 1979. Approximately four-fifths of the total NPK was used for food production and the rest was for estate crops (Table 3.3)

Table 3.3
Consumption of NPK
(mt)

Year	Food Sector		Estate Sector		Total
	Total	%	Total	%	
1	2	3	4	5	6 = 2+4
1967	48,871	59	34,252	41	83,123
1968	119,894	83	25,386	17	145,280
1969	192,458	85	35,292	15	227,750
1970	197,291	80	50,159	20	247,450
1971	226,648	90	26,718	10	253,366
1972	251,373	77	76,671	23	328,044
1973	379,205	91	38,257	9	417,462
1974	393,319	92	36,727	8	430,046
1975	422,555	88	62,171	12	484,726
1976	415,590	86	69,995	14	485,585
1977	557,844	86	91,532	14	649,376
1978	617,579	81	146,074	19	763,653
1979	698,748	82	157,202	18	855,950
Average of Annual Rate Growth					
1967 - 73	47.50	%			
1973 - 76	3.17	%			
1976 - 79	19.36	%			

Source : Direktorat Bina Sarana Usaha Tanaman Pangan, 1977/79

Consumption of NPK in the food sector increased significantly from 48,871 mt in 1967 to 379,205 mt in 1973 or at about 47.50 percent annually. The substantial increase of consumption from 1972 to 1973 was caused by the increase in Bimas area planted from 1,203,000 ha to 1,832,000 ha,; also, total area planted increased from 6,602,000 ha to 7,064,000 ha. There was a drought in 1972 and total area planted as well as area under Bimas was below that of 1971. In 1973 the government enacted (rationing) controls in the distribution system to ensure adequate supply of fertilizer to Bimas participants (Slayton and Exawirya 1978, pp.77). This was implemented due to the world shortage of fertilizer following the oil crisis. On 19 November 1974 the government announced an increase in the price of fertilizer from Rp 40 to Rp 60/kg and price of gabah from Rp 39.60 to Rp 55.50/kg as from 1 February 1975 (Booth and Glassburner 1975, pp.20-25). This meant that the fertilizer to gabah price ratio increased from 1.01 to 1.09. As a result consumption of fertilizers tapered off between 1974 and 1975. The same situation occurred when the government increased the price of fertilizer from Rp 26.60/kg in 1973 to Rp 40/kg in 1974 (Prices of fertilizer and gabah are given in Appendix A.3.1).

Again on 28 October 1975 the government announced a new price of fertilizer and floor price of gabah for the Bimas programme. The fertilizer price was raised by 33 percent to Rp 80/kg and the price of gabah was raised by 18 percent to Rp 65/kg (McCawley 1976, pp.26-32). The fertilizer to gabah price ratio increased from 1.09 to 1.23. The government explanation for the increase in both the price of rice and of fertilizer was to reduce subsidies and to encourage the farmers to become efficient. Consequently, consumption of NPK was nearly constant from 1974 to 1976, and even decreased by about 2 percent from

422,555 mt in 1975 to 415,590 mt in 1976. Government controls were dismantled in 1976 (Rice and Lim 1976, pp.11-16). That resulted in the fertilizer price being the same for Bimas and Non-Bimas, and Non-Bimas farmers could buy either from BUUD/KUD centres or from other retailers. In that year, the price of fertilizer was decreased to Rp 70 and the price of gabah increased to Rp 71 from February 1977 (McCawley and Manning 1976, pp.2-9). As a result, consumption of NPK increased drastically from 415,590 mt in 1976 to 557,844 mt in 1977, about 34 percent. The annual rate of growth of NPK consumption was about 3 percent between 1973 and 1976 and was about 19 percent between 1976 and 1979. The new price of fertilizer was increased in November 1982 from Rp 70 to Rp 90 per kg (McCawley 1983, p.23).

At the same time as demand for NPK was rising, the government increased domestic production. Consequently, the proportion of NPK imported fell drastically from 80 percent of total supply between 1967 and 1975 to only about 20 percent between 1976 and 1979. The amount of import fluctuated annually depending on domestic consumption. Between 1967 and 1976, imports increased at 33.54 percent annually but decreased between 1978 and 1979 due to the increase in domestic production (Table 3.4).

Overall, the growth rate of imports was 21.70 percent annually between 1967 and 1979, 12.02 percent below the average growth rate of domestic production (33.72 percent).

Table 3.4

Supply of NPK
(mt)

Year	Imports	%	Domestic Production	%	Total Supply
1	2	3=2:6	4	5=4:6	6 =(2 + 4)
1967	83,337	66	43,481	34	126,818
1968	209,167	83	44,319	17	253,486
1969	182,102	82	39,568	18	221,670
1970	139,963	75	45,569	25	185,532
1971	149,483	76	48,229	24	197,712
1972	329,918	85	60,099	15	390,017
1973	338,974	81	81,783	19	420,757
1974	690,324	85	122,051	15	812,375
1975	1,002,441	83	209,108	17	1,211,549
1976	48,395	21	185,393	79	233,788
1977	106,759	21	396,646	79	503,405
1978	234,023	25	694,757	75	928,780
1979	140,556	13	926,533	87	1,067,089
Average of Annual Rate Growth					
1967-76	33.54		20.20		
1967-79	21.70		33.72		
1976-79	-13.80		74.20		

Source : Direktorat Bina Sarana Usaha Tanaman Pangan, 1977 and 1979

During the period 1972-1975 the Government of Indonesia experienced a situation of excess supply. This was due to the Government's stockpiling policy in the light of the threatening scarcity of fertilizer in the world market as a result of the oil crisis in 1973. As a consequence, in 1975 supply was greatly in

excess of current demand (Table 3.5).

Table 3.5

Supply and Consumption of NPK
(mt)

Year	Supply	Consumption	Surplus (+) Deficit (-)	Stock *
1	2	3	4 = (2 - 3)	5
1967	126,818	83,123	+ 43,695	43,695
1968	253,486	145,280	+ 108,206	151,901
1969	221,670	227,750	- 6,206	145,821
1970	185,532	247,450	- 6,198	139,623
1971	197,712	253,366	- 55,654	83,969
1972	390,017	328,044	+ 61,973	145,942
1973	420,757	417,462	+ 3,295	149,237
1974	812,375	430,046	+ 382,329	531,566
1975	1,211,549	484,726	+ 726,823	1,258,389
1976	233,788	485,585	- 251,797	1,006,592
1977	503,405	649,376	- 145,971	860,621
1978	928,780	763,653	+ 165,127	1,025,748
1979	1,067,084	855,950	+ 211,134	1,236,882

Source : Extracted from Table 3.3 and Table 3.4

* : There are no data on stock of NPK before 1967

Excess supply peaked in 1975 at 726,823 mt by comparison with only 61,973 mt in 1972, 3,295 mt in 1973 and 382,329 mt in 1974. The excess supply between 1972 and 1975 accumulated, firstly because the average application estimate of 250 kg/ha for Bimas and Inmas programme participants were not fulfilled (250 kg/ha), and secondly,

because there were no accurate figures of domestic stocks. For example, officials did not know that many farmers had saved supplies of fertilizer which they had not used.

Since a large proportion of NPK was carried over to the following years, the Government reduced imports and encouraged exports. Notwithstanding the deficit of fertilizer in 1976 (251,797 mt) and in 1977 (145,971 mt), domestic consumption was still fulfilled because stocks of fertilizer remained high due to the availability of previous stocks. In 1978 and 1979 there were surpluses of NPK amounting to 165,127 mt and 211,134 mt due to an increase in domestic production. This left large quantities for exports. In this period the government exported urea to Africa, Asia and Oceania. In 1978 total exports of urea was 230,462 mt and in 1979 were 299,299 mt.

3.3 Distribution of Fertilizer

3.3.1 Marketing Institutions

In 1957 Government of Indonesia established Jabatani (Jajasan Bahan Pertanian - Foundation for Agricultural Inputs) to make fertilizers and equipment available to farmers. For supply to farmers Jabatani obtained fertilizer from private importers and distributed it through private traders and cooperatives. However, they often could not obtain fertilizer from Jabatani due to frequent shortages. Due to its failure, Jabatani in 1959 was taken over by the Paddy Centres [1].

[1] The Paddy Centres were established in 1959 in relation to 3 years programme known as "operation prosperity". The target was to set up 250 centres to cover 1.5 million hectares by 1961/62. Farmers in each area were given credits in the form of fertilizer, seeds and cost of living with repayment to be made in kind with dry stalk paddy, generally at price below the prevailing price in local markets (Truc, 1975; Timmer 1975, pp.195-231).

The main goals of the Paddy Centres were to increase production of rice by providing fertilizer and seed to the farmers and to act as purchasing centres for Government rice requirements. However, this programme failed (Timmer 1975, p.210) because : (a) farmers reacted unfavourably to the centralization of the programme, (b) the easy credit in the programme were badly abused by the officials and the farmers, and (c) the programme was set up on very short notice. Due to its failure the Paddy Centres were closed down in 1963 and their functions were replaced by PN Pertani (Kolff 1971, p.58).

PN Pertani was established in 1961. Until 1967 PN Pertani held an official monopoly and controlled distribution of fertilizer to the sub-district (Kecamatan) level. From 1963 to 1967 the farmers were faced with difficulties in obtaining fertilizer since it was frequently unavailable. The reasons were the lack of foreign exchange to pay for fertilizer imports, and inefficiency in distribution. In addition, PN Pertani had insufficient control over the stock of fertilizer and over the price because it was not given sufficient authority. The government then established Bimas Gotong Royong [2] in 1968 to overcome these difficulties. However, the situation led to large excess fertilizer stocks, poor quality, and inefficiency in distribution to the farmers. There were several reasons for the failure of Bimas Gotong Royong: (a) the programme was located in areas where water supplies were inadequate, (b) the rigid package of

[2] Bimas Gotong Royong- BGR - (Mutual self-help) was established to provide rice areas with fertilizer and pesticides to increase yields. The Government contracted several foreign companies to provide these inputs such as CIBA, AHT, Mitsubishi, Geigi and Hoechst (Timmer 1975, p.215).

inputs caused the farmers to resell part of their fertilizer on the market at cut prices, and (c) it had a negative effect on the market structure and credit institutions since it neglected commercial enterprises. Hence, the government was forced to pay more attention to private traders, since they could operate efficiently. There were several reasons why private traders could compete with PN Pertani during 1960s. Private traders were often selling Pusri urea which was more popular than other brands, while PN Pertani sold imported urea. In addition, private traders provided better service than PN Pertani. Until 1967 PN Pertani was the sole legal distributor of PT Pusri. Because PN Pertani made many failures in distribution, the Government demonopolized it by opening the fertilizer trade to a number of private distributors (Truc, 1975).

The new system of distribution commenced in 1976 by allowing the private sector to sell fertilizer at subsidized prices (Warr 1980, pp.7-14); it was expected to improve distribution and increase use of fertilizer and also to help decrease the incentive for Bimas farmers to sell part of their allotted fertilizer. Of total fertilizer around 72 percent in 1976 was distributed through the Bimas programme and the rest through private traders. Under the Bimas programme, farmers having less than five hectares of land were provided with short-term credit (7 months) at one percent per month in the form of subsidized inputs and a cash grant for operating costs (Table 3.6).

Table 3.6

Bimas Credit Package : Irrigated Rice (per ha)
1980/81

Description	Packet A		Packet B	
	Quantity	Value (Rp)	Quantity	Value (Rp)
Fertilizer				
Urea	200 kg	14,000	100 kg	7,000
TSP	50 kg	3,500	35 kg	2,450
Insecticide	2 lt	2,460	2 lt	2,460
Rodenticide	100 gr	400	100 gr	400
Seeds		5,000		0
Spraying and Expenses		2,000		2,000
Additional Expenses for Intensification		10,000		10,000
Total Value		40,860		27,810

A for HYV

B for Local Varieties

Source : Department of Agriculture, 1980

However, the new system launched in 1976 led to the unexpected result that Bimas participation rate has since been declining. Mears (1981) argued that the farmers who had their own capital increasingly left the Bimas programme and followed the Inmas programme where credit is not involved. In addition, private traders could now compete by purchasing fertilizer for cash at the district level (Line III) and resell it to the farmers sufficiently below the regulated price for them to buy it at the proper time. Slayton and Exawirya (1978, p.80) proposed several reasons for the decline in the Bimas programme, such as: (a) denial of credit by BRI (Bank Rakyat Indonesia) to participants who had defaulted on previous Bimas loans, (b) increased

risk associated with wereng damage to HYV of rice contained in the Bimas package, and (c) possible decline in the profitability of using Bimas programme. According to them the most serious reason was the denial of credit

3.3.2 Distribution Costs and Margins

The major points in the fertilizer distribution chain are called "lines" (World Bank 1978, pp.75-76) and can be defined as follows:

Line 1 - fertilizer plant or port of entry

Line 2 - domestic production, ex-bulk unloading and bagging terminal

Line 3 - major inland distribution point

Line 4 - retail outlet

Government appointed importers/distributors of fertilizer act as authorized importers and distributors of subsidized fertilizer. Importers/distributors obtain the supply of fertilizer from Line 1 and 2 and distribute it to wholesalers or sub-distributors at Line 3 or district level. Sub-distributors in Line 3 then distribute fertilizer to retailers at Line 4 or village cooperatives. The distribution of fertilizer for Bimas is under the supervision and control of the provincial governor as Head of Bimas Guiding Body and district head as the Head of the Bimas Executing Body. Sub-distributors of fertilizer at district level are appointed by the Bimas executing Body. They cover a number of villages and channel the fertilizer supply through the village unit cooperative (KUD) and to private retailers. The warehouse of these sub-distributors are usually owned or hired from

private sources. A Flow chart of fertilizer distribution is given in Appendix A.3.2.

For imported urea, bagging plants in the port area are indicated as Line 1 storage from where fertilizer is transported to storage outside the port area (Line 2 storage). The fertilizer is then distributed by either road or rail to the district storage (designated as Line 3). Sub-distributors then distribute fertilizer to the village retail storage (designated in Line 4). For domestic production, fertilizer mostly comes from Palembang (PT Pusri), Sumatra, and it is shipped in bulk to ports of the main island where it is bagged and distributed up to Line 4.

The margins in Line 1, 2, 3 and 4 are determined by the government. Distribution costs and margins are shown in Table 3.7.

Table 3.7

Examples of Government Calculation of Marketing Margins
for Fertilizer [5] in Rp/kg

Effective	Dec.10, 1976		Sep.18, 1978		Apr.17, 1980	
	Rp.	%	Rp.	%	Rp.	%
World Price (Rp/kg)	48.00 [2]	68.6 [3]	87.50	125.0	130.0	185.7
Less Subsidy (estimate)	11.35	16.2	38.67	55.2	88.6	126.6
Releases Price to Importer or Producer [1]	36.65	52.4	48.83	69.8	41.4	59.1
Importer handling Costs and Fee	12.82	18.3 !				
Government Receives	10.00	14.3 !				
Selling Price Line II (FOT) [4]	59.47	85.0 !				
Line II to III		!				
Credit	0.24	0.3 !				
Transport Line II and Unloading	3.28	4.7 !	12.17	17.4 !	18.0	25.8
Losses	0.24	0.3 !				
Cost Line III	63.23	90.3 !				
Storage Line III	0.65	0.9 !				
Losses	0.54	0.8 !				
Loading out	0.25	0.4 !				
Selling price Line III (FOT)	64.67	92.4	61.00	87.2	59.4	84.9
Transport to Line IV and Unloading	1.85	2.6	2.95	4.2 !		
Distributors fee	0.97	1.4	2.25	3.2 !	6.6	9.4
Losses	na	na	0.30	0.4 !		
Cost to Village Retailer (KUD)	67.50	96.4	66.50	95.0	66.0	94.3
Losses and Reconditioning handling Fee	0.25	0.4	0.25	0.4 !	4.0	5.7
	2.25	3.2	3.25	4.6 !		
Price to Farmer	70.00	100.0	70.00	100.0	70.0	100.0

[1] Bagged

[2] CIF= Cost, insurance and freight

[3] FOB= Free on Board

[4] FOT= Free on Truck

[5] Refers to Urea

Source : Mears, L.A., 1981, p.307

Chapter 4

DEMAND ANALYSIS

4.1 Introduction

Theoretically time-series data are more appropriate than cross-sectional data for the estimation of economic relationships (Koutsoyiannis, 1977). However, the assumption that different periods of time are homogeneous, except for differences in the explicit variables and in random effects of the function as measured, has created some problems. The important problem is an intercorrelation of the explanatory variables which tends to change over time. Hence we cannot have full confidence in the accuracy of our estimate. On the other hand from cross-sectional data it is assumed that different units (households, regions, etc.) are homogeneous except for differences in the measured variables and the error term. For a single period of cross-section data, price variables and other market variables such as interest rates, wages, etc. are held constant. Hence we cannot obtain an estimate of the price coefficient since the price structure is the same for all the consumers at any particular point of time.

To avoid the problems associated with either time-series or cross-section data alone we can combine or pool them. Pooling data in a model with both time-series and cross-section explanatory variables then becomes an acceptable procedure (Pindyck, 1981). Some advantages of pooling cross-section and time-series data are as follows [1] : first, it can avoid the presence of multicollinearity; second, it can

[1] For detail see Klein (1962) and Koutsoyiannis (1977).

avoid the identification problem; third, it can avoid least square simultaneous-equation bias, and fourth, it can avoid an aggregation bias due to changes in the distribution of income. On the other hand there are also some disadvantages of pooling techniques as put forward by Koutsoyiannis (1977). They are, first, problems of interpretation of the function estimated from the application of the pooling technique arise [2], second, problems of accuracy of the cross-section estimates result, third, problems arise from the reference of the cross-section estimate to a single point of time, and fourth, problems of adjustment of the cross-section elasticities are raised.

4.2 Techniques of Pooling Data

The classical linear model assumes that the error term was not autocorrelated [$\text{Cov}(e_i e_j) = 0$] and has constant variance i.e. is homoskedastic [$\text{Var}(e_i) = \sigma^2$]. In matrix notation both assumptions can be written as $E(ee') = \sigma^2 I$, where I is an $N \times N$ identity matrix. Sometimes, when dealing with pooled data these assumptions can no longer be held and we must assume that serial correlation and heteroskedasticity are present. To solve this problem we can apply the modified GLS (Generalized Least Square) method (Murphy, 1973). To allow for both serial correlation and heteroskedasticity assumptions, the covariance matrix can be written as $E(ee') = \Omega$. Where Ω is a known symmetric positive definite matrix of order n . By retaining all other assumptions of the classical normal regression model except for

[2] Klein (1962) suggested some ways of interpreting the longrun and shortrun function.

nonautocorrelation and homoskedasticity we have the so-called GLS.

Kmenta (1971) gives the description of this model as follows:

1. $Y = \beta_1 + \beta_2 X_{12} + \beta_3 X_{13} + \dots + \beta_k X_{1k} + e_i$
2. The joint distribution of e_1, e_2, \dots, e_n is multivariate normal,
3. $E(e_i) = 0, (i = 1, 2, \dots, N)$
4. $E(e_i e_j) = \sigma_{ij} (i, j = 1, 2, \dots, N)$
5. Each of the explanatory variables is nonstochastic and such that,

for any sample size, $\frac{1}{N} \sum_{i=1}^N (X_{ik} - \bar{X}_k)$ is a finite

number different from zero every $k = 2, 3, \dots, K$

6. The number of observations exceeds the number of explanatory variables plus one; i.e., $N > K$
7. No exact linear relation exists between any of the explanatory variables.

By assuming that the stochastic error term is distributed normally with mean zero and covariance matrix Ω , that is, $e \sim N(0, \Omega)$, the BLUE (Best, Linear and Unbiased Estimator) can be derived. This estimator can be obtained using the technique of maximum likelihood (Intriligator, 1978). Where the estimator is:

$$\hat{\beta} = (X' \Omega^{-1} X)^{-1} X' \Omega^{-1} Y \quad (1)$$

$$\text{Cov}(\hat{\beta}) = \sigma^2 (X' \Omega^{-1} X)^{-1} \quad (2)$$

$$\hat{\beta} \sim N[\beta, \sigma^2 (X' \Omega^{-1} X)^{-1}] \quad (3)$$

By applying an appropriate transformation of observation the GLS method above can be demonstrated to be equivalent to OLS (Ordinary Least Square) method. Mathematically, a positive definite matrix can be presented in the form $P'P$ where P is a non singular (Johnston, 1972). Because Ω is a symmetric positive definite matrix, so is Ω^{-1} . This implies that

$$\Omega^{-1} = P'P \quad (4)$$

By inserting this (4) in the GLS estimator equation (1) yields

$$\hat{\beta} = (X'P'PX)^{-1} X'P'PY \quad (5)$$

and the least-squares estimator of the transformed model can be expressed as follows:

$$\tilde{Y} = \tilde{X} + \tilde{e} \quad (6)$$

$$\text{where: } \tilde{Y} = PY$$

$$\tilde{X} = PX$$

$$\tilde{e} = Pe$$

$$E(\tilde{e}) = E(Pe) = PE(e) = 0$$

$$E(\tilde{e}\tilde{e}') = PE(ee')P' = \sigma^2 P \Omega P' = \sigma^2 I.$$

Here Pe satisfies the classical least-squares assumption that is has zero mean and $Cov(ee') = \sigma^2 I$. Hence the OLS method can be applied to the data after applying transformation as demonstrated above. Transformation observation that is from Ω to $\sigma^2 I$ is carried out to remove serial correlation and heteroskedasticity (this method is given in Appendix A.4.1). There are some techniques of pooling data by transformation of observation. In this study only three techniques will be applied as explained below.

4.2.1 A Cross-sectionally Heteroskedastic and Time-wise Autoregressive Model (CHTWAM)

By this model we combine the assumptions both about cross-sectional and time-series observations. On the cross-sectional observations it is assumed that the regression errors are mutually independent but heteroskedastic, and on the time-series observations it is assumed that the errors term are autoregressive. With pooling data we combine these assumptions with characteristics (Kmenta, 1971) as follows:

Consider the model

$$Y = \chi\beta + e \quad (7)$$

1. $E(e_{it}^2) = \sigma_i^2$ heteroskedasticity
2. $E(e_{it}e_{jt}) = 0 (i \neq j)$ cross-sectional independence
3. $e_{it} = \rho_i e_{i,t-1} + U_t$ autoregression

where $U_{it} \sim N(0, \sigma_{ui}^2)$

$$e_{io} \sim N(0, \frac{\sigma_{ui}^2}{1-\rho^2})$$

$$E(e_{i,t-1}U_{jt}) = 0$$

4. $E(e_{it}e_{is}) = \rho^{t-s}\sigma_i^2 (t > s)$
5. $E(e_{it}e_{js}) = 0 (i \neq j)$

In this model we estimate the elements of matrix $\Omega = \text{diag} (\sigma_i \rho_i)$

where:

$$\rho_i = \begin{bmatrix} 1 & \rho_i & \rho_i^2 & . & . & \rho_i^{T-1} \\ \rho_i & 1 & \rho_i & . & . & \rho_i^{T-2} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \rho_i^{T-1} & \rho_i^{T-2} & \rho_i^{T-3} & . & . & 1 \end{bmatrix}$$

Element of Ω can be found by following way (Kmenta, 1971; Murphy, 1973). First, the OLS method is applied to the original model (7) based on all (NT) observations. From this regression, the regression residual e_{it} are calculated and can be used to calculate estimate of ρ_i (i.e. $\hat{\rho}_i$) by

$$\hat{\rho}_i = \frac{\sum e_{it} e_{i,t-1}}{\sum e_{i,t-1}^2} \quad (t = 2, 3, \dots T) \quad (8)$$

Second, having done $\hat{\rho}_i$, this value is used to transform the observations to remove autoregressive, that is, by forming :

$$\tilde{Y}_{it} = \beta_1 \tilde{X}_{it,1} + \beta_2 \tilde{X}_{it,2} + \dots + \beta_k \tilde{X}_{it,k} + \tilde{u}_{it}$$

where:

$$\begin{aligned} \tilde{Y}_{it} &= Y_{it} - \hat{\rho}_i Y_{i,t-1} & (9) \\ \tilde{X}_{it,k} &= X_{it,k} - \hat{\rho}_i X_{i,t-1,k} & (t = 2, 3, \dots, T) \\ & & (k = 1, 2, \dots, K) \\ \tilde{U}_{it} &= e_{it} - \hat{\rho}_i e_{i,t-1} & (i = 1, 2, \dots, N) \end{aligned}$$

Third, the OLS method is applied to the equation (9) above with $N(T-1)$ observations. From this regression, regression residuals u are calculated and can be used to estimate the variance of u_{it} (i.e. $\sigma^2_{u_i}$) by

$$S^2_{ui} = \frac{\sum_{t=2}^T \hat{u}_{it}^2}{T-K-1} \quad (10)$$

since $e_{io} \sim N(0, \frac{\sigma^2_{ui}}{1-\rho_i^2})$
 $\sigma^2_{ui} = \sigma^2_i (1-\rho_i^2)$ it follows that

σ^2_i can be estimated by

$$S^2_i = \frac{S^2_{ui}}{1-\hat{\rho}_i^2} \quad (11)$$

Fourth, having done the transformed observation to remove autoregression, the transformed observation is carried out to remove heteroskedasticity. This transformation is conducted by dividing both

side of equation (9) by Su_i obtained from equation (10) above as follows :

$$\tilde{Y}_{it} = \beta_1 \tilde{X}_{it,1} + \beta_2 \tilde{X}_{it,2} + \dots + \beta_K \tilde{X}_{it,K} + \tilde{U}_{it} \quad (12)$$

where:

$$\tilde{Y}_{it} = \frac{\tilde{Y}_{it}}{S_{ui}} \quad (i = 1, 2, \dots, N)$$

$$\tilde{X}_{it,k} = \frac{\tilde{X}_{it,k}}{S_{ui}} \quad (t = 2, 3, \dots, T)$$

$$\tilde{U}_{it} = \frac{\tilde{U}_{it}}{S_{ui}} \quad (k = 1, 2, \dots, K)$$

After transformation the error u_{it} is asymptotically nonautoregressive and homoskedastic.

Fifth, the final equation (12) can be estimated by applying the OLS method based on $N(T-1)$ pooled observations giving estimates with the same asymptotic properties as obtained by using the GLS method.

Another way to solve this model can be carried out by assuming that the parameter ρ has the same value for all cross-sectional units, i.e.,

$$\rho_i = \rho_j = \rho - \text{for all } i = j = 1, 2, \dots, N$$

The first step can be conducted exactly the same as the above step except the formula (8) for $\hat{\rho}$ is replaced by

$$\hat{\rho} = \frac{\sum_i \sum_t e_{it} e_{i,t-1}}{\sum_i \sum_t e_{i,t-1}^2} \quad (13)$$

$$(i = 1, 2, \dots, N)$$

$$(t = 2, 3, \dots, T)$$

Having done this variables in equation (9) are transformed by using (13) above and the remaining steps are similar to the step above.

4.2.2 A Cross-sectionally Correlated and Time-wise Autoregressive Model (CCTWAM)

In this model the assumption that the cross-sectional units are mutually independent is no longer held. For example the cross-sectional units might be geographical regions such as Java (West Java, Central Java, and East Java) and other islands in which the demand pattern in one region is likely to influence the demand pattern in other regions. Hence we cannot expect that the assumption of mutual independence is satisfied. By relaxing this assumption the specification of this model will be different from the Cross-sectionally heteroskedastic one above. The specification of the error term of this model (Kmenta, 1971) is as follows:

Consider the model $Y = x\beta + e$ (14)

1. $E(e_{it}^2) = \sigma_{ii}$ cross-sectional heteroskedasticity
2. $E(e_{it}e_{jt}) = \sigma_{ij}$ cross-sectional mutual correlation of disturbances
3. $e_{it} = \rho_i e_{i,t-1} + U_{it}$ autoregression

where:

$$U_{it} \sim N(0, \sigma_{ii}),$$

$$E(e_{i,t-1}U_{jt}) = 0,$$

$$E(U_{it}U_{js}) = 0, (t \neq s)$$

$$(i, j = 1, 2, \dots, N)$$

$$4. e_{i0} \sim N(0, \frac{\sigma_{ii}}{1-\rho_i^2})$$

$$5. E(e_{i0}e_{j0}) = \frac{\sigma_{ij}}{1-\rho_i\rho_j}$$

For these properties the autoregressive schemes are assumed to be appropriate even at the initial observation. That is, the first observation is not the first period in a strikingly novel environment but rather a continuation of the same type periods in which the autoregressive scheme has been operating (Murphy, 1973). The matrix Ω form for this model is no longer diagonal $\sigma_{ii} \rho_{ii}$ due to relaxation of the assumption of mutual independent.

The matrix Ω is as follows:

$$\Omega = \begin{bmatrix} \sigma_{n'n} & \sigma_{12'n12} & \cdot & \cdot & \sigma_{1N'n1N} \\ \sigma_{21'21} & \sigma_{22'22} & \cdot & \cdot & \sigma_{2N'2N} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \sigma_{N1'N1} & \sigma_{N2'N2} & \cdot & \cdot & \sigma_{NN'NN} \end{bmatrix}$$

where

$$\rho_{ij} = \begin{bmatrix} 1 & \rho_j & \rho_j^2 & \cdot & \cdot & \rho_j^{T-1} \\ \rho_i & 1 & \rho_j & & & \rho_j^{T-2} \\ \rho_i^2 & \rho_i & 1 & \cdot & \cdot & \rho_j^{T-3} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \rho_i^{T-1} & \rho_i^{T-2} & \rho_i^{T-3} & \cdot & \cdot & 1 \end{bmatrix} \quad (15)$$

Consistent estimates of the elements Ω can be found by following (Kmenta, 1971; Murphy, 1973) way:

First, the OLS method is applied to the original model (14) based on all (NT) observations. From this regression the residuals e_{it} are calculated and are used to calculate $\hat{\rho}_i$ by applying

$$\hat{\rho}_i = \frac{\sum e_{it}e_{i,t-1}}{\sum e_{i,t-1}^2} \quad (16)$$

$$(t = 2, 3, \dots, T)$$

Second, the value of $\hat{\rho}$ is used to transform the observations.

We form,

$$\tilde{Y}_{it} = \beta_1 X_{it,1} + \beta_2 \tilde{X}_{it,2} + \dots + \beta_k \tilde{X}_{it,k} + \tilde{U}_{it} \quad (17)$$

where:

$$\tilde{Y}_{it} = Y_{it} - \hat{\rho}_i Y_{i,t-1}$$

$$\tilde{X}_{it,k} = X_{it,k} - \hat{\rho}_i X_{i,t-1,k}$$

$$\tilde{U}_{it} = e_{it} - \hat{\rho}_i e_{i,t-1}$$

$$U_{it} = e_{it} - \hat{\rho}_i e_{i,t-1}$$

$$(t = 2, 3, \dots, T)$$

$$(i = 1, 2, \dots, N)$$

$$(k = 1, 2, \dots, K)$$

Third, the OLS method is applied to equation (17) above to remove autoregressive scheme. From this regression we calculate the residual u_{it} which can be used to estimate variances and covariances e 's (i.e. σ_{ij}) by

$$s_{ij} = \frac{\hat{\sigma}_{ij}}{1 - \hat{\rho}_i \hat{\rho}_j} \quad (i \neq j)$$

where:

$$\hat{\sigma}_{ij} = \frac{\sum_{t=2}^T \hat{U}_{it} \hat{U}_{jt}}{T-K-1}$$

$$s_j^2 = \frac{\hat{\sigma}_j^2}{1 - \hat{\rho}_j^2} \quad (j = 1, 2, \dots, N)$$

where:

$$\hat{\sigma}_j^2 = \frac{\sum_{t=2}^T \hat{u}_{jt}^2}{T-K-1}$$

From this regression we will find consistent estimates of ρ_i and σ_{ij} and therefore (Kmenta, 1971).

4.2.3 Covariance Model

The assumption underlying the models above, that of the constancy of the intercept and slope may be unreasonable in a pooled model. The differences in demand pattern across regions are likely to cause differences on both intercept and slope over time and over cross-section units. Hence, if they vary significantly over time and over cross-section units, pooling would be inappropriate. To allow for differences in intercept and slope the time-series and cross-section data are pooled together and for each region a dummy variable is introduced in a Covariance model (Judge et al., 1982; Maddala, 1977). This can be written as follows:

$$Y_{it} = \alpha + \beta X_{it} + \lambda_2 W_{2t} + \lambda_3 W_{3t} + \dots + \lambda_N W_{Nt} + \dots \\ + \zeta_2 Z_{i2} + \zeta_3 Z_{i3} + \dots + \zeta_T Z_{iT} + e_{it}$$

where: $W_i = 1$ for i th individual

0 otherwise

$Z_t = 1$ for t th time period

0 otherwise

($i = 1, 2, \dots, N$)

($t = 2, 3, \dots, T$)

Coefficients of λ_1 and ζ_1 are omitted since their addition would cause perfect collinearity among the explanatory variables. The dummy variable coefficients estimate the change of intercept in the cross-section and time series. This can be carried out by eliminating dummy variables and rewriting the model related to each of all (NT) observations as follows:

$$Y_{11} = \alpha + \beta X_{11} + e_{11}$$

$$Y_{12} = (\alpha + \zeta_2) + \beta X_{12} + e_{12}$$

.

$$Y_{1T} = (\alpha + \zeta_T) + \beta X_{1T} + e_{1T}$$

$$Y_{21} = (\alpha + \lambda_2) + \beta X_{21} + e_{21}$$

$$Y_{22} = (\alpha + \lambda_2 + \zeta_2) + \beta X_{22} + e_{22}$$

.

$$Y_{2T} = (\alpha + \lambda_2 + \zeta_T) + \beta X_{2T} + e_{2T}$$

$$Y_{N1} = (\alpha + \lambda_N) + \beta X_{N1} + e_{N1}$$

$$Y_{N2} = (\alpha + \lambda_N + \zeta_2) + \beta X_{N2} + e_{N2}$$

$$Y_{NT} = (\alpha + \lambda_N + \zeta_T) + \beta X_{NT} + e_{NT}$$

Parikh (1965, pp.1-19) and David (1976, pp.107-123) adopted this model in estimating demand for fertilizer in some countries. Some problems can emerge with the use of the covariance model (Pindyck, 1981; Maddala, 1977). That is, first, the use of dummies does not directly identify the variables which might cause the regression line to shift over time and over individuals. And, second, it uses up a great number degrees of freedom which causes a decrease in the statistical power of the model.

Another model that can overcome this problem is the error component model (Maddala, 1977; Judge et al., 1982) which has been analyzed in depth by Chetty (1968, pp.279-290), Nerlove (1971, pp.359-382), Maddala (1971, pp.939-953) and Balestra and Nerlove (1966, pp.585-612). However there are also some problems with the error component model (Pindyck, 1977). They are firstly computation can be quite expensive because the application of the GLS estimation involves the inverse of an $NT \times NT$ matrix. Secondly, the technique is not directly applicable if there are lagged dependent variables in the equation or if the equation is part of simultaneous equation model. And, thirdly, this model has the property that the correlation of error over time is independent of the time gap between the error term. An alternative specification to allow error assumption involving time-series autocorrelation as well as cross-section heteroskedasticity is model 4.2.2 above. However, as mentioned above the weakness of model 4.2.2 is its assumption on the constancy of slope and intercept.

Having considered the model we have discussed above we will now consider the functional form.

4.3 Functional Form

In this study two direct demand models - dynamic and static - will be examined. For the dynamic model the Brown model (1952, pp.355-371) is adopted, that is,

$$C_t = \beta_0 + \beta_1 Y + \beta_2 C_{t-1} + u$$

Where: C_t is consumption of a particular good in year t

Y_t is disposable income in year t

C_{t-1} is the lagged consumption level, and

u_t is the error term

Assumptions underlying this model are:

1. The lagged effect in consumer demand was produced by the the consumption habits which people formed as a result of past consumption.

2. The 'habit persistence' effect induced on current behaviour by past consumption would be strongest when t is small and vanishes as t becomes larger. Brown used lag consumption as one of the independent variables to account for the slowness in the reaction of consumer demand to the changes in income. This slowness is caused by the inertia or "hysteresis" in consumer behaviour such as habits, customs, standards, and levels associated with real consumption

previously enjoyed. This model hypothesizes that current consumption is not influenced by previous income but by previous real consumption [3]. The static model used is that of Houthakker (1965, pp.277-288), Stone et al. (1954) and others [4]. The choice of suitable form is a more empirical matter since theory does not always impose the determination of choosing the appropriate functional form for the equation being estimated (Tomek and Robinson, 1972; Houtakker and Taylor, 1966) [5]. A functional form for demand analysis to be applied in this study both for dynamic and static model is double-log function. This function implies a constant elasticity and a constant percentage relation of demand throughout the relationship between dependent and independent variables. Its functional form is as follows,

$$X = \alpha_1 P_1^{\beta_1} P_2^{\beta_2} P_N^{\beta_N} I^\lambda e^{\zeta_t} + U_t$$

-
- [3] Brown called this hypothesis a habit "hysteresis" or habit persistence theory which differ from the permanent income hypothesis (Friedman, 1957). The differences between these are in the nature of regressors, interpretation of the error term and non linearity in parameters (for detail see Singh and Ullah 1973, pp.96-103).
- [4] Analysis of demand theory - dynamic and static - was analyzed in depth by Bridge (1971), Wold and Jureen (1953), Ekelund et al. (eds., 1972) and Schultz (1938).
- [5] Different direct demand functions (double-log, log inverse, semi-log, linear, and hyperbola) were applied to some products by Prais and Houtakker (1955). They came to conclusion that the satisfactoriness of the functions is not only dependent on their assumption underlying the model but also on the kind of product to be examined.

where:

X is demand for a particular good

P_1, \dots, P_N are prices

t is time and

u is error term with usual assumption

Taking logarithms result in log linear representation,

$$\ln X = \alpha + \beta_1 \ln P_1 + \beta_2 \ln P_2 + \dots + \beta_N \ln P_N + \lambda \ln I + \zeta t + u$$

Where the coefficients β_1, \dots, β_N and λ provide direct estimates of price and income elasticities, respectively, and ζ provides an estimate of instantaneous rate of growth (Chiang, 1974).

That is,

$$\beta_1 = E = -\frac{\delta \ln X}{\delta \ln P_1} = \frac{\delta X}{\delta P_1} \cdot \frac{P_1}{X}$$

$$\beta_N = E_N = -\frac{\delta \ln X}{\delta \ln P_N} = \frac{\delta X}{\delta P_N} \cdot \frac{P_N}{X}$$

$$\lambda = \eta = \frac{\delta \ln X}{\delta \ln I} = \frac{\delta X}{\delta I} \cdot \frac{I}{X}$$

$$\zeta = \frac{\delta \ln X}{\delta t} = \frac{1}{X} \cdot \frac{\delta X}{\delta t}$$

There are many other alternative functional forms [6], but since this model has been the most commonly used (Intriligator, 1978), as well as because of limitations of data and time, this form will be applied and other models are not considered further in this study.

Demand functions to be applied are as follows:

a. CHTWAM and CCTWAM

$$\ln F = \alpha + \beta \ln F_{TOP} + \lambda \ln F_{t-1} + \eta IRR + e \quad (\text{dynamic model})$$

$$\ln F = \alpha + \beta \ln F_{TOP} + \eta IRR + e \quad (\text{static model})$$

where:

F = Fertilizer (NPK) application kg/ha

F_{TOP} = Fertilizer to Paddy Price Ratio

IRR = Proportion of Irrigated land

F_{t-1} = Lagged consumption of fertilizer

α = Intercept

β = Coefficient of F_{TOP}

η = Coefficient of IRR

λ = Coefficient of F_{t-1}

e = Error term

[6] Instead of using direct demand model indirect or derived demand model is also widely used in estimating demand for inputs such as fertilizer, labor etc. Some studies such as Sidhu and Baanante (1979, pp.455-462) using Cobb-Douglas Profit Function in estimating Fertilizer Demand for Mexican Wheat Varieties in the Indian Punjab; while Pitt (1981, pp.1-18) applied Translog Profit Function and Box-Cox transformation in estimating farm-level fertilizer demand in Java.

b. Covariance Model

$$\begin{aligned}
 \text{Ln } F &= \alpha_1 + \sum_{K=2}^9 \alpha_K D_K + \beta_1 \text{Ln } F\text{TOP} + \sum_{K=2}^9 \beta_K \text{Ln } F\text{TOP} + \\
 &\quad + \lambda_1 \text{Ln } F_{t-1} + \sum_{K=2}^9 \lambda_K \text{Ln } F_{t-1} + e \quad (\text{dynamic model}) \\
 \text{Ln } F &= \alpha_1 + \sum_{K=2}^9 \alpha_K D_K + \beta_1 \text{Ln } F\text{TOP} + \sum_{K=2}^9 \beta_K \text{Ln } F\text{TOP} + \\
 &\quad \eta \text{IRR} + e \quad (\text{static model})
 \end{aligned}$$

where :

F = Fertilizer (NPK) application kg/ha

F\text{TOP} = Fertilizer to Paddy P ce Ratio

IRR = Proportion of Irrigated land

F_{t-1} = Lagged consumption of fertilizer

$\alpha_1 \dots, \alpha_K$ = Separate intercept terms

$\beta_1 \dots, \beta_K$ = Separate slope terms

For region (1) the intercept term is α_1

For region (2) the intercept term is $(\alpha_1 + \alpha_2)$, etc

For region (1) the slope term is β_1

For region (2) the slope term is $(\beta_1 + \beta_2)$, etc

D_K = Dummy for region

Region (1) = West Java

Region (2) = Central Java (D_2)

Region (3) = East Java (D_3)

Region (4) = North Sumatra (D_4)

Region (5) = Central Sumatra (D_5)

Region (6) = South Sumatra (D_6)

Region (7) = Sulawesi (D_7)

Region (8) = Kalimantan (D_8)

Region (9) = Bali (D_9)

4.4 The Data

All the data used in this study are secondary data. Cross-sectional data come from of nine regions: West Java, Central Java, East Java, North Sumatra, Central Sumatra, South Sumatra, Sulawesi, Kalimantan and Bali. Data from each region cover eleven years from 1969 to 1979. Data for fertilizer are published by the Department of Agriculture while data for production of paddy and area planted are published by the Central Bureau of Statistics. Data for irrigated land are published by Department of Public Works while data relating to the price of fertilizer and the price of paddy are collected from Nota Keuangan and other sources (BIES).

In this study the relevant prices used are the Government-set price of fertilizer and of paddy. We will use the fertilizer to paddy price ratio (both set by Government) to examine the impact changing these prices on fertilizer demand. The same method was applied by Hsu (1972, pp.299-309) in examining Government policy in agricultural development in Taiwan. The limitation of the data derives from their being compiled from official sources which inevitably tend to bias. All such data used in the analysis are given in Appendix A.4.2.

4.5 Empirical Results

Two empirical results - dynamic and static models - are presented by pooling, and making the structural test to determine whether data can be pooled or not. The F test (Maddala, 1977) applied is as follows:

To test H_1 : $\alpha_1 = \alpha_2 = \dots = \alpha_N$

$\beta_1 = \beta_2 = \dots = \beta_N$

$$F = \frac{[RSS(R) - RSS(UR)] / (2N - 2)}{RSS(UR) / (T - 2N)}$$

($i = 1, 2, \dots, N = \text{regions}$)

($t = 1, 2, \dots, T = \text{observations}$)

RSS(R) Restricted Residual Sum of Squares

RSS(UR) Unrestricted Residual Sum of Squares

Having run the dynamic model, however the result (see Appendix A.4.3 and A.4.4) produces negative coefficient of lag fertilizer except for North Sumatra, Kalimantan and Bali which contradicts our assumptions that demand of fertilizer is determined positively by past usage.

However the static model provides a statistically significant result of the relative price. Therefore all subsequent analysis will use the static model.

In the static model we use irrigation instead of lagged fertilizer as the independent variable as well as the relative price. The sign of the relative price is expected to be negative as before while for irrigation we expect a positive sign, indicating that there was a positive growth rate of irrigated land. The result of CHTWAM and CCTWAM model are shown in Table 4.1.

Table 4.1
CHTWAM and CCTWAM

Variables	Coefficient Estimates	
	CHTWAM	CCTWAM
Constant	3.211 (6.804)**	1.690 (6.133)**
Ln FTOP	- 0.824 (-2.524)**	- 1.120 (-5.318)**
IRR	0.018 (2.368)**	0.042 (11.388)**
R ²	0.799	0.811
\bar{R}^2	0.795	0.807
F	190.240 **	205.517 **
DW	2.259	2.294
RSS(R)	41.235	38.782
RSS(UR)	23.073	23.073
F (pooling test)	3.540 **	3.062 **

Values in parentheses are t values

RSS(R) Restricted Residual Sum of Squares

RSS(UR) Unrestricted Residual Sum of Squares

** significant at 1%

The coefficient of all regression estimates for the two models have the expected signs. However for the pooling test F value was calculated as 3.540 and 3.062 for CHTWAM and CCTWAM respectively. This value is significant at 1 percent level indicating that the data cannot be pooled due to significant differences in slope and intercept across regions.

The differences in slope and intercept across regions are shown by applying a Covariance model (Table 4.2).

Table 4.2

Covariance Model

Regions	Intercept	Ln FTOP	IRR
Region specific coefficient for slope and intercept			0.012 (1.133)
1 West Java	3.685 (6.857)**	-0.806 (-1.785)*	
2 Central Java (D_2)	3.778 (5.923)**	-1.306 (-3.257)**	
3 East Java (D_3)	3.988 (5.362)**	-1.412 (-4.853)**	
4 North Sumatra (D_4)	3.878 (9.103)**	-1.436 (-2.386)**	
5 Central Sumatra (D_5)	3.054 (3.808)**	-0.999 (-2.123)**	
6 South Sumatra (D_6)	3.795 (10.949)**	-2.223 (-5.793)**	
7 Sulawesi (D_7)	2.400 (4.515)**	-2.738 (-4.193)**	
8 Kalimantan (D_8)	0.740 (1.183)	-2.618 (-1.429)*	
9 Bali (D_9)	3.955 (9.230)**	-2.525 (-3.168)**	
R^2	0.871		
\bar{R}^2	0.847		
F	36.960**		
DW	1.853		
RSS(R)	26.530		
RSS(UR)	23.073		
F(pooling test)	0.727		

Values in parentheses are t values

RSS(R) Restricted Residual Sum of Squares

RSS(UR) Unrestricted Residual Sum of Squares

* significant at 5%

** significant at 1%

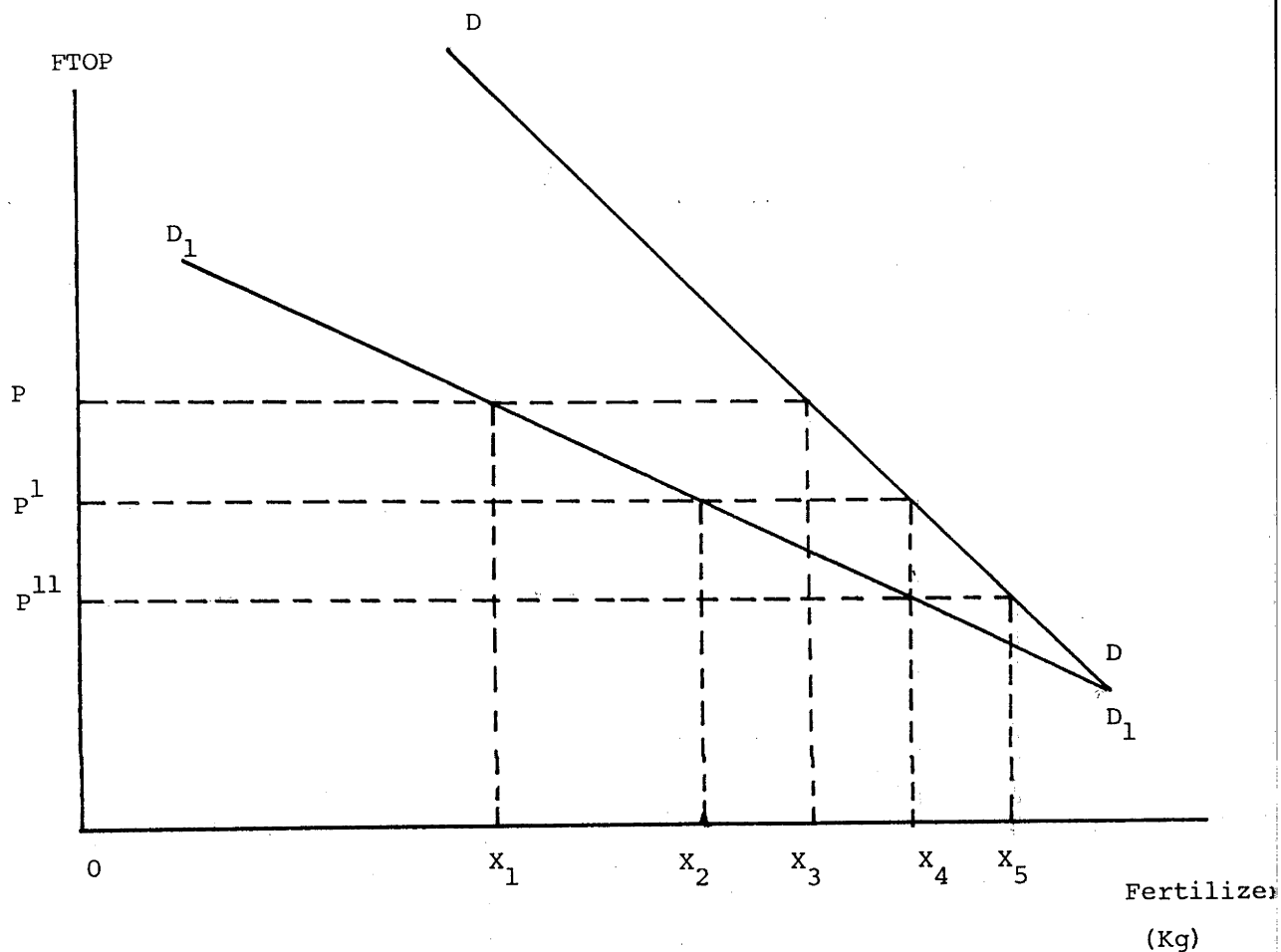
The regression coefficient will yield the long run elasticities as the regional-effect is held constant while the year-effect is varying in the equation. (The short run elasticities could be estimated by carrying out a similar regression with both year and region dummies).

All the coefficients of the relative price are as expected. They have negative signs and are significant at 1 percent level except for Kalimantan which is significant at 5 percent level. This means that in the long run the fertilizer to paddy price ratio plays an important role in determining demand for fertilizer. The elasticity of the relative price varies from -0.806 in West Java to -2.738 in Sulawesi. This coefficient would indicate that if the fertilizer to paddy price ratio increases by 1 percent 'ceteris paribus' the fertilizer use can be predicted to decline by 0.806 percent in West Java and 2.738 percent in Sulawesi. The coefficient of the relative price is inelastic only in West Java while in Central Sumatra it is close to unity and in the rest is above unity. The high elasticity of the relative price may be caused by difficulties in obtaining fertilizer at times in some regions. However as a whole the figures indicate that the relative price plays a significant role in determining the demand level for fertilizer. Irrigation has a positive sign as anticipated but is not significant.

A high relative price elasticity for South Sumatra, Sulawesi, Kalimantan and Bali can be interpreted in two possible ways.

First, the high elasticity can be explained by relating it to the fertilizer market situation in which, after 1976, there was a great improvement in distribution. This can be shown in Figure 4.1.

Figure 4.1
Estimated Demand Function



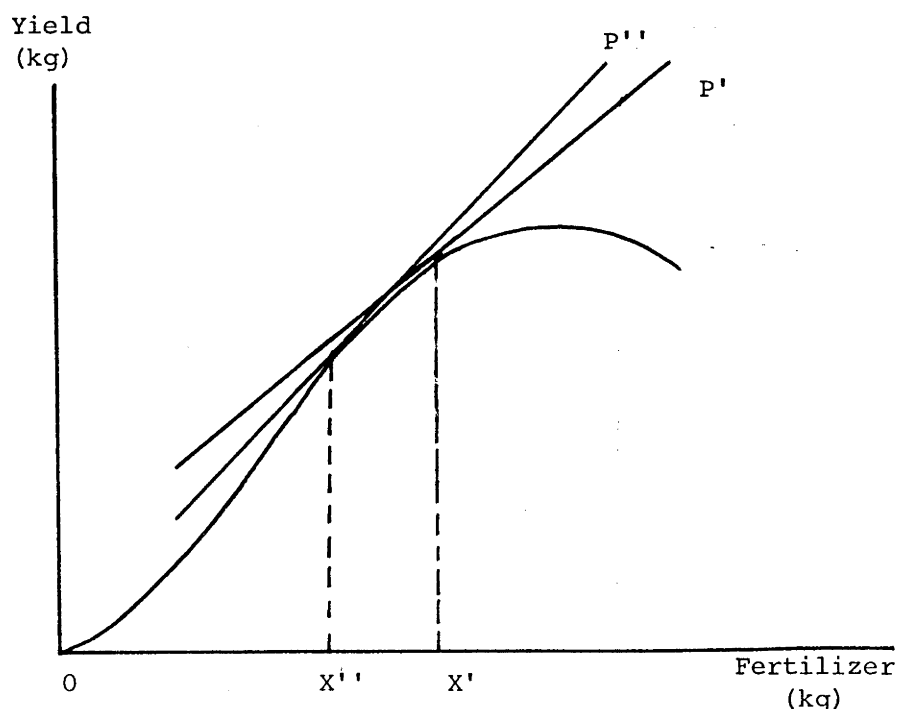
Suppose DD is the demand function we are trying to estimate. At price P the amount of fertilizer available is X_1 while quantity demanded is X_3 . So there is excess demand of the amount X_1X_3 . When the relative price declines to P' , and there are also improvements in marketing, the fertilizer available is X_2 (greater than X_1), and the excess demand X_2X_4 will be smaller than X_1X_3 . This situation continues until there is no excess demand due to perfect distribution of fertilizer. This occurs at the intersection of $D'D'$ and DD . We

can see that $D'D'$ is more elastic than DD , the demand function which we want to estimate. $D'D'$ is neither the actual demand nor the supply function but a curve which shows the availability of fertilizer due to successive improvements in marketing and price falls. This situation may have happened in Sulawesi, Kalimantan and South Sumatra where the application of fertilizer after 1976 increased.

Second, the high elasticity can be explained by specifying that the demand function for fertilizer is derived demand. In this case if the applied fertilizer use has been high a small increase in the relative price would have resulted in a great decrease in fertilizer use. This is shown in Figure 4.2.

Figure 4.2

Response Curve
for a single variable input



Suppose the initial relative price is P' with X' amount of fertilizer use. If the relative price increase to P'' the fertilizer use will decrease from X' to X'' . The diagram shows that a small increase in the relative price causes a substantial decline in fertilizer use for postulated response function. This situation could have happened in Bali where the average fertilizer use was 66.2 kg/ha (1969 - 1979) while the average use of fertilizer for all regions was 53.3 kg/ha for the same period. In addition Bali has relatively higher soil fertility.

For comparison, estimated elasticities of fertilizer demand for other Asian countries are given in Table 4.5.

When we use pooling techniques there are no great differences between the relative price elasticities given in Table 4.5 and the results given in our study. However due to significant differences in slope and intercept across regions in Indonesia we cannot compare the relative price elasticities of nine regions in Indonesia with the relative price elasticities of other countries. By allowing for the differences between intercept and slope, comparison between nine regions in Indonesia and other countries require more information about these countries and interregional differences where significant.

Table 4.5

Summary of Fertilizer Demand Selected
Asian Developing Countries

Country	Time Period	Fertilizer price elasticity of demand		Remarks
		Short Run	Long Run	
India	1953/4-67/68	-0.31	-0.32	Contains area irrigated (Source M.S. Rao)
		-0.53	-6.63	Excludes irrigated area (Source: M.S. Rao)
	1958/59-63/64	-1.20	-2.50	Covariance Analysis (Source: A. Parikh)
	1950 - 1972	-1.671		Covariance Analysis (Source: C.C. David)
South Korea	1950 - 1972	-0.931		Covariance Analysis (Source: C.C. David)
Sri Lanka	1950 - 1972	-0.818		Covariance Analysis (Source: C.C. David)
Philippines	1966 - 1971	-0.902		Covariance Analysis (Source: C.C. David)
Thailand	1967 - 1976	-0.759		Linear Demand Functions (Source: ARSAP)
		-0.746		Log form (Source: ARSAP)

Source : APO, 1979
FRIS, 1976

4.6 Policy Implications

The result of this demand analysis suggests that the relative price plays a significant factor in determining the demand for fertilizer. The government can stimulate farm fertilizer use by manipulating either the price of rice or the price of fertilizer, or

both.

1. Output side (rice)

Despite a government fixed floor price of rice to support the farmers there is some evidence that they did not receive this price (Dick 1979, p.37). Some farmers, especially small farmers, did not sell their product directly to KUD but to village traders (usually large farmers) or to the manager of the KUD because this way the farmers could obtain consumption credit. In addition, the farmers were often informed that BULOG had not yet made credit available to the KUD. This enabled private traders to buy rice at harvest time cheaply and resell it to the KUD later at the (higher) floor price. Private traders not restricted by the official floor price earned higher profit margins on rice bought at the lower farmgate price. Furthermore, while BULOG had the power to buy rice it never bought more than 5 percent of total domestic crop yet the proportion marketed above village-level is probably at least 25 percent (Dick 1979, pp.37-38; Mears 1981, pp.491-502). Hence it appears that some of the benefit from price support policy accrued to private traders and KUD officials rather than to farmers as intended.

2. Input side (fertilizer)

In addition to maintaining a support price for rice the government expects fertilizer subsidization can help the farmers. The total amount of fertilizer subsidy has increased markedly recently to about 3 percent of the total national budget (Dick 1982, p.31).

Krishna (1963) suggested that if the objective is to accelerate innovation and the growth of agricultural output then input subsidization policy is an appropriate method. When the objective of self-sufficiency has been achieved then fertilizer subsidy will no longer be required. This subsidy can be relaxed without diminishing production once the farmers become familiar with fertilizer usage. The most direct effect of the subsidy removal would thus be an immediate reduction in farmers income. A fertilizer subsidy is also one of the ways in which farmers rather than urban dwellers have shared in the benefits of oil revenue in Indonesia (Dick 1982, p.32).

There is an entire spectrum of views on the relative merits of output and input subsidies in agricultural production in developing countries (Krishna, 1963; Timmer 1975, pp.419-432; Barker and Hayami 1976, pp.617-628; Parish and McLaren 1982, pp.1-13). According to the conventional wisdom, an output subsidy is more efficient than an input subsidy as a means of increasing output since an output subsidy does not distort the choice of inputs away from the least-cost combination (Parish and McLaren 1982, p.1). However it is also suggested that input subsidies may be a more cost-effective way of increasing output both from the government's and society's points of view, provided the subsidized input satisfies some conditions :

- a. a high elasticity of supply.
- b. high substitutability for factors of fixed or relatively inelastic supply, and
- c. low substitutability for other inputs the supply of which is elastic.

Fertilizer seems to satisfy all these conditions in the Indonesian case, being in elastic supply, a land substitute and complement of other inputs.

The result shows obtained in our study that the long run relative price (fertilizer to paddy price ratio) elasticities are very high in some regions. These indicate that a small increase in the relative price is likely to result in a substantial decline in fertilizer use in the long run. However, with the farmers (especially Javanese farmers) now becoming more aware of the advantages of using fertilizer (eg. higher yields), with improved distribution of fertilizer, and increased and sustained supply of fertilizer, the long run implication is probably that the farmer's use of fertilizer may not be affected substantially even if the government's subsidy is withdrawn. Therefore, higher yields can be sustained without continued subsidies, although the abolition of the subsidy would lead to a once-over decline in farm incomes.

Chapter 5

SUMMARY AND CONCLUSION

This chapter consists of three sections. The first section presents a summary of the theoretical framework, limitations of the data and functions used, and the empirical results. The second section presents some implications of the study for government policies in relation to output and input subsidization. The third section recommends areas for further research in the light of the limitations highlighted in this study.

5.1 Summary of Findings

Rice is the most important food crop and a main staple food in Indonesia, and its price is of primary concern to the Indonesian Government. Between 1968 and 1979 per capita production of rice increased at an annual rate of 1.6 percent while per capita consumption grew at an average rate of 2.3 percent. To close this gap several programmes have been launched. Existing production incentives were extended by intensifying the Bimas programme, attempts were made to improve rice marketing by establishing Bulog and the KUDs, and price incentives - fixing floor and ceiling price for rice and fertilizer - were adopted. Until the mid-1970s, average fertilizer use was less than the recommended rate (Bimas) of 250 kg/ha. Given that fertilizer use is determined not only by its own price but also by the paddy price, the government has tried to manipulate both prices to increase fertilizer use.

The aim of this study has been to estimate changes in the demand for fertilizer by using the fertilizer to paddy price ratio (hereafter called "the relative price") and the proportion of irrigated land as explanatory variables. Previous studies indicate that fertilizer usage has played an important role in agricultural development. In some developing countries (India, Indonesia, Philippines, Srilanka, and Thailand) the estimated contribution of fertilizer to the growth rate of production is very high (ADB, 1977). A great potential for increasing fertilizer use is still unexploited in developing countries. Typically, countries with low levels of fertilizer use are developing countries, conversely developed countries have high level of fertilizer use (FAO 1979, cited in Arnon 1981, p.313). Some factors influencing fertilizer usage are environment, farmers' educational and economic levels, and particularly, relative prices of fertilizer/paddy. IRRI data (Palacpac, 1982) indicate that the lower the relative price of fertilizer to paddy the higher the fertilizer use and the rice yield.

After rapid increases in fertilizer use in the foodcrop sector between 1969 and 1973, fertilizer consumption tapered off between 1974 and 1976. In response, the government in 1976, decreased the price of fertilizer by 12.5 percent (to Rp 70/kg) and increased gabah price by 9 percent (to Rp 71/kg). As a result fertilizer consumption increased markedly in 1977. But despite a surplus of fertilizer nationally many farmers often could not obtain fertilizer due to distribution inefficiencies. Fertilizer availability improved after the government allowed the private traders to be involved in distribution, and set the same prices of fertilizer for Bimas and non-Bimas farmers. This policy was intended to increase fertilizer consumption and to prevent

farmers reselling their fertilizer allotted in the Bimas package. However the result was that Bimas participation decreased further, as farmers tended to buy from the private traders offering fertilizer at lower price and on demand. Also farmers shifted to the Inmas programme where credit is not necessarily involved.

The fertilizer price set by the government is heavily subsidized. In 1977 the amount of subsidy was Rp 11.35/kg, about 16.2 percent of the retail price (Rp 70/kg). This subsidy further increased in 1979 to Rp 38.67/kg, about 55.2 percent of the retail price, and increased markedly to Rp 88.60, 126.6 percent of the retail price in 1980. Not surprisingly the consumption of fertilizer increased, reflecting the growing subsidization of fertilizer price.

By introducing dummy variables to estimate a demand function for fertilizer, the relative price elasticity of demand in each region was as follows:

Region	Relative price elasticity of demand
West Java	- 0.806
Central Sumatra	- 0.999
Central Java	- 1.306
East Java	- 1.412
North Sumatra	- 1.436
South Sumatra	- 2.223
Bali	- 2.515
Kalimantan	- 2.618
Sulawesi	- 2.738

The high coefficient elasticity in South Sumatra, Sulawesi and Kalimantan may reflect the improvement in fertilizer distribution since 1976, while in Bali it may reflect existing high usage levels and fertile soil. This result also may reflect the limitations of data and the function used. For example: (a) the data are compiled from different sources, (b) the price used is not the prevailing market price, (c) the fertilizer use data are not direct farm-level observations, and (d) the demand for fertilizer is a derived demand so farm level data should be used. In addition the function might be trapped by a simultaneous equation bias eventhough the pooling technique has an advantage in the simultaneous equation problem [1].

High elasticities of demand mean an increase in the relative price would lead to a sharp decline in fertilizer use, 'ceteris paribus'. Since the estimated demand function refers to long run demand this means the government in the long run should not increase the fertilizer to paddy price ratio if the intended aim is to increase fertilizer use. As a consequence, as fertilizer is already heavily subsidized, the rich farmer, who uses most of it will receive most benefit. This may lead to widening income disparities both through the direct impact on farmer incomes and through the indirect impact on increased land values. On the other hand it can be argued that Indonesian farmers are now aware of the benefit of fertilizer use and some increase in the fertilizer to paddy price ratio may not affect demand.

[1] An indirect demand function or two stages equations cannot be derived due to lack of data.

On the other side output subsidies are hardly feasible in a largely subsistence agriculture such as Indonesia's where more than 50 percent of production is not marketed. Moreover support price policies do not work properly since KUDs are not effectual. Hence, it appears that the benefit from price support is not fully enjoyed by the farmers.

5.2 Suggestion for Further Research

For further analysis of demand for fertilizer in Indonesia to be undertaken additional data, and new methodologies are required. The data required are the prevailing market prices of rice and the price of fertilizer in each region and actual fertilizer use at farm level. Also further explanatory variables could be used such as seed, area under HYVs, farmer's knowledge, and risk, to obtain more representative and reliable results.

As for methodology, further research can be conducted by applying the indirect demand approach instead of the direct demand approach, since demand for fertilizer is a derived demand (Mundlak 1963, pp.138-166; Pitt 1981, pp.1-18; Sidhu and Baanante 1976, pp.237-246). Or a complete simultaneous equation system can be used to avoid the effect of simultaneous equation bias where the data used are aggregate data. Also information on market structure is required when we are estimating the demand function since the result can be biased if there is excess demand in the market as there almost certainly was in many parts of Indonesia in the early 1970s.

Appendix

Table A.2.1

Characteristics of Countries According to their
Fertilizer Environment

	Group 1 Industrializ ed(East Asia Japan,Korea Taiwan)	Group 2 Industrializ ing (Indonesia, Malaysia, Philippines)	Group 3 Pre-industrial (Continental Southeast Asia Burma, Cambodia Thailand, Vietnam)
Population density	250-350	75-125	50-100
Rural population (%)	below 45%	60-75%	over 75%
Per capita income (US\$)	500-3000	150-800	below 150
Farm size structure	smallholders	smallholders plantations	smallholders
Rate of tenancy	very low	medium	high
Topography	mountainous	mountainous	flat
Controlled irrigation	over 90%	15-30%	below 10%
Economic and environmental risks	low	medium	medium-high
Rice acreage under HYV (%)	100%	40-60%	below 10%
Food grain/cash crop ratio	1.2-5.0	0.2-2.6	over 9
Yield (kg of paddy/ha)	over 4500- 5800	1600-2600	1200-1700
Source of food crop price support	industry	plantation crops,oil mineral.	none
Producer's rice price	26-60 stable	14.5-22 partly stable	below 12 unstable
% of recent output growth explained by increased yield	over 95	50-80	below 50
Side income possibilities	good	some	none
Domestic fertilizer production	net surplus	30-50% of requirement	none
	Crops	accounting for most of the fertilizer used	
Nitrogen	rice	rice	rice
Phosphate	rice	rice,oil palm sugarcane	rice
Potash	rice	oil palm, sugarcane	vegetables, fruits tobacco, sugarcane
Present growth rate in fertilizer consumption	slow to moderate	fast	slow
Fertilizer usage per ha (kg NPK)	200-300	25-75	below 10

Source : Uexkull, 1975

Appendix

Table A.3.1

Official Rice and Fertilizer Prices, 1969-83
(Rp/kg)

Period	Fertilizer[a]	Unmilled rice (<u>Gabah</u>) [b]	Price ratio
	(1)	(2)	(3)=(2):(1)
1969	26.60	18.40	1.45
1970	26.60	18.40	1.45
1971	26.60	18.40	1.45
1972	26.60	18.40	1.45
1973	26.60	18.40	1.45
1974	40.00	39.60	1.01
1975	60.00	55.50	1.09
1976	80.00	65.00	1.23
1977	70.00	71.00	0.99
1978	70.00	75.00	0.93
1979	70.00	85.00	0.82
1980	70.00	105.00	0.67
1981	70.00	120.00	0.58
1982	70.00	135.00	0.52
1983	90.00	145.00	0.62

[a] Urea

[b] Purchasing price for KUDs (Cooperatives) from farmers
unmilled dry paddy (Gabah)

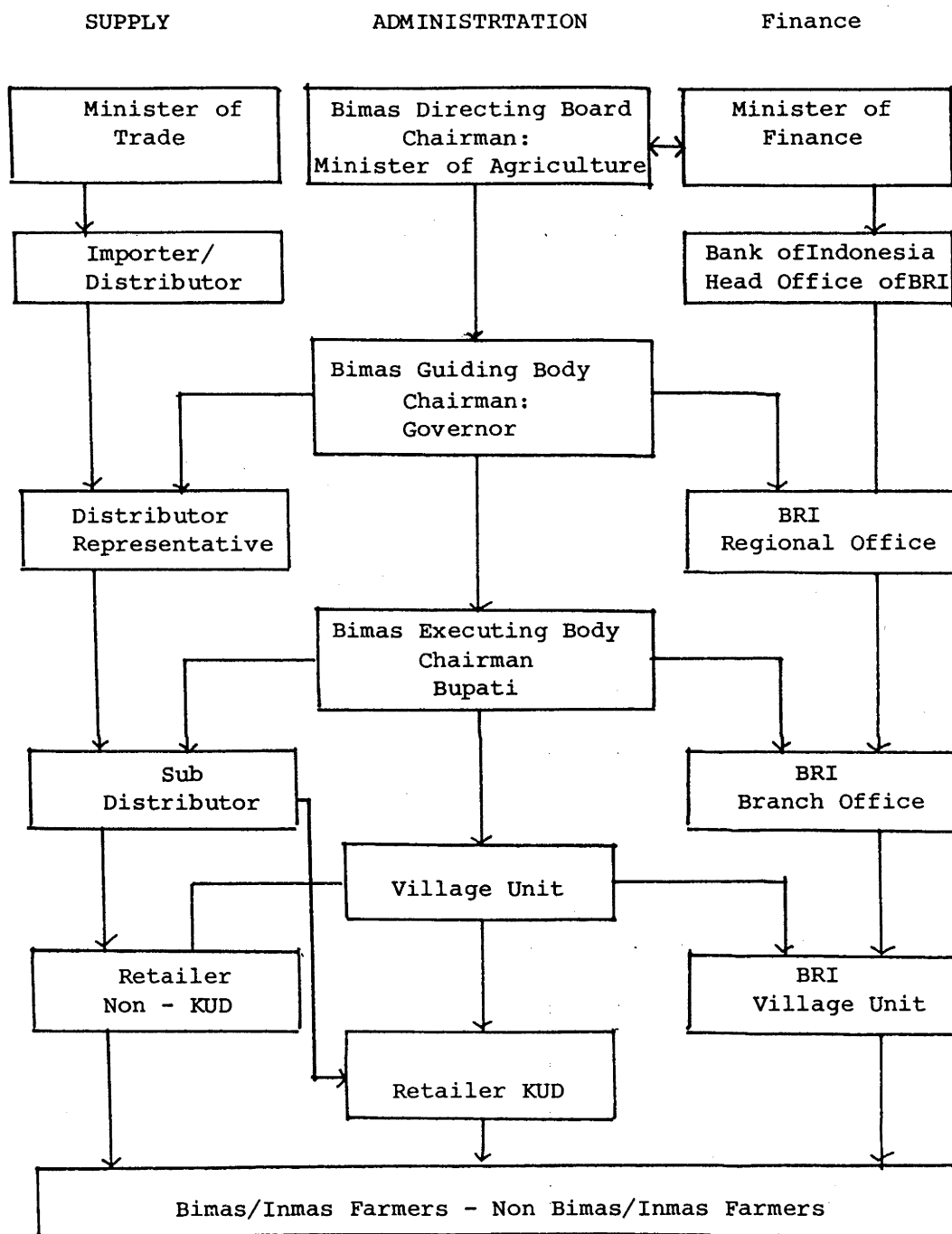
Source : BIES, March 1976; April 1983

Nota Keuangan

Appendix

Figure A.3.2

Flow Chart of Fertilizer Distribution



Source: Mulyono, B., 1979.

Appendix A 4.1

SOLUTION FOR SERIAL CORRELATION AND HETEROSKEDASTICITY

Consider the model

$$Y_i = \beta_1 + \beta_2 X_{i2} + \beta_3 X_{i3} + \dots + \beta_k X_{ik} + e_i, \text{ or in short,}$$

$$Y = X\beta + e$$

where: Y is an $(n \times 1)$ vector of the sample values of Y ,

X is an $(n \times k)$ matrix of the sample values of X_{i1} ,

X_{i2}, X_{ik} (with $X_{i1} = 1$ for all i)

β is a $(k \times 1)$ vector of the regression coefficients, and

e is an $(n \times 1)$ vector of the sample values of e

The assumption $E(e_i e_j) = \sigma_{ij}$ where $i, j = 1, 2, \dots, N$ (other assumptions are given in Chapter 4) can be written as

$$E(ee') = \Omega$$

where:

$$\Omega = \begin{bmatrix} \sigma_{11} & \sigma_{12} & . & . & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & . & . & \sigma_{2n} \\ . & . & . & . & . \\ . & . & . & . & . \\ \sigma_{n1} & \sigma_{n2} & . & . & \sigma_{nn} \end{bmatrix}$$

This model is called 'generalized' because it includes other models as special case (Kmenta, 1971) that is Ω is diagonal but the diagonal elements are not necessarily all the same.

On the classical linear least square we know that $E(ee') = \sigma^2 I_n$.

Let us consider the case if $\Omega = \sigma^2 I_n$, this implies $\Omega^{-1} = \frac{I_n}{\sigma^2}$ and

Aitken's generalized estimator is the same as the OLS estimator.

In the case of heteroskedasticity without serial correlation, the covariance matrix is of the form

$$\Omega = \begin{bmatrix} \sigma_{11} & & 0 \\ & \sigma_{22} & \\ 0 & & \sigma_{nn} \end{bmatrix}$$

And the inverse used in GLS estimator is then

$$\Omega^{-1} = \begin{bmatrix} \frac{1}{\sigma_{11}} & & 0 \\ & \frac{1}{\sigma_{22}} & \\ 0 & & \frac{1}{\sigma_{nn}} \end{bmatrix}$$

In the case of serial correlation without heteroskedasticity, if

$$\begin{bmatrix} 1 & \rho & \rho^2 & . & . & \rho^{n-1} \\ \rho & 1 & \rho & . & . & \rho^{n-2} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ \rho^{n-1} & \rho^{n-2} & \rho^{n-3} & . & . & 1 \end{bmatrix}$$

that is, if the first-order autoregressive (Markov) process is followed, the corresponding covariance matrix of the stochastic error term is

$$\Omega^{-1} = \frac{1}{\sigma^2(1-\rho^2)} \begin{bmatrix} 1 & -\rho & 0 & 0 & . & . & 0 & 0 \\ - & (1+\rho^2) & -\rho & 0 & . & . & 0 & 0 \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ 0 & 0 & 0 & 0 & . & . & -\rho & 1 \end{bmatrix}$$

The solution for both serial correlation and heteroskedasticity are as follows:

A. SOLUTION FOR SERIAL CORRELATION

A.1 GLS Solution

Covariance matrix of serial correlation can be shown as follows:

$$E(ee') = \sigma_e^2 = \Omega = \begin{bmatrix} 1 & \rho & \rho^2 & . & . & \rho \\ \rho & 1 & \rho & . & . & \rho \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ \rho^{n-1} & \rho^{n-2} & \rho^{n-3} & . & . & 1 \end{bmatrix} \quad \text{where,} \quad \sigma_e^2 = \frac{\sigma_u^2}{1-\rho^2}$$

Because matrix e is not scalar the OLS method is inefficient, and the best linear unbiased estimates of β can be estimated by GLS. From above are known that the distribution follows a first-order scheme, and if value of the parameter ρ is known then GLS can be applied. Identity matrix Ω can be carried out by multiplying Ω^{-1} by Ω , so $\Omega^{-1} \Omega = I_n$ and the matrix form is

$$\Omega^{-1} = \frac{1}{\sigma_u^2(1-\rho^2)} \begin{bmatrix} 1 & -\rho & 0 & . & 0 & 0 & 0 \\ -\rho & 1+\rho^2 & -\rho & . & 0 & 0 & 0 \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & -\rho & 1+\rho^2 & -\rho \\ 0 & 0 & 0 & . & 0 & -\rho & 1 \end{bmatrix}$$

So the GLS estimator is $\hat{\beta} = (X^1 \Omega^{-1} X)^{-1} X^1 \Omega^{-1} Y$

A.2 Transformation Solution

An alternative solution is by transforming equation $Y_t = \beta X_t + e_t$ so that errors become uncorrelated, hence satisfying the OLS method.

Three steps procedure (Judge et al, 1982) are carried out as follows:

1. Find a matrix P such that $P'P = \Omega^{-1}$
2. Calculate the transformed observations $\tilde{Y} = PY$ and $\tilde{X} = PX$
3. Apply least squares to the transformed model $\tilde{Y} = \tilde{X}\beta + \tilde{e}$,
where $\tilde{e} = Pe$, to obtain the GLS estimator $\hat{\beta} = (\tilde{X}'\tilde{X})^{-1} \tilde{X}'\tilde{Y}$

We use the matrix P to transform the original model as follows:

$$PY = PX\beta + Pe$$

$$\tilde{Y} = \tilde{X}\beta + \tilde{e}$$

will have a scalar dispersion matrix, i.e. $E(\tilde{e}\tilde{e}') = \sigma^2 I_n$

Consider the $n \times n$ matrix P

$$\begin{bmatrix} 1-\rho^2 & 0 & 0 & . & . & 0 & 0 & 0 \\ -\rho & 1 & 0 & . & . & 0 & 0 & 0 \\ 0 & -\rho & 1 & . & . & 0 & 0 & 0 \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & . & -\rho & 1 & 0 \\ 0 & 0 & 0 & . & . & 0 & -\rho & 1 \end{bmatrix}$$

The error term \tilde{e} is consistent with the classical liner model since

$$P\Psi P' = I_n, \text{ so } E(\tilde{e}\tilde{e}') = E(Pee'P) = \sigma^2 P\Psi P' = \sigma^2 I_n = \Omega, \text{ since}$$

$$E(ee') = \sigma^2 \Psi$$

then OLS may be applied to the transformed observation PY and PX

shown in matrix form as follows:

$$\begin{bmatrix} \sqrt{1-\rho}^2 Y_1 \\ Y_2 - \rho Y_1 \\ \cdot \\ \cdot \\ Y_n - \rho Y_{n-1} \end{bmatrix}, \quad \begin{matrix} \hat{Y} \\ (PY) \end{matrix} = \begin{bmatrix} \sqrt{1-\rho}^2 & \sqrt{1-\rho}^2 X_{2,1} & \cdot & \sqrt{1-\rho}^2 X_{k,1} \\ 1-\rho & X_{2,2} - \rho X_{2,1} & \cdot & X_{k,2} - \rho X_{k,1} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 1-\rho & X_{2,n} - \rho X_{2,n-1} & \cdot & X_{k,n} - \rho X_{k,n-1} \end{bmatrix}, \quad \begin{matrix} \hat{e} \\ (Pe) \end{matrix} = \begin{bmatrix} \sqrt{1-\rho}^2 e_1 \\ -\rho e_1 + e_2 \\ \cdot \\ \cdot \\ -\rho e_{n-1} + e_n \end{bmatrix}$$

By substituting PY and PX for Y and X in the OLS estimator

$\hat{\beta} = (X'X)^{-1}X'Y$ we find

$$\begin{aligned}\hat{\beta} &= [(PX)' PX]^{-1} (PX)' PY \\ &= [X'(P'P)X]^{-1} X' (P'P)Y, \text{ or} \\ &= (\tilde{X}'\tilde{X})^{-1}\tilde{X}'\tilde{Y} \text{ which is the same as } \Omega^{-1} \text{ in GLS solution} \\ \text{that is } P'P &= \Omega^{-1} \text{ where,}\end{aligned}$$

$$P'P = \begin{bmatrix} 1 & -\rho & 0 & . & . & 0 & 0 \\ - & 1-\rho^2 & - & . & . & 0 & 0 \\ 0 & -\rho & 1+\rho^2 & . & . & 0 & 0 \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ 0 & 0 & -\rho & . & . & 1+\rho^2 & -\rho \\ 0 & 0 & 0 & . & . & -\rho & 1 \end{bmatrix}$$

From above we can see that the first observation is treated differently from the rest. The first observation is transformed as follows:

$$\begin{aligned}1. \quad \sqrt{1-\rho^2} Y_1 &= \sqrt{1-\rho^2} X_1 \beta + \tilde{e}_1 \\ \text{where } \tilde{e}_1 &= \sqrt{1-\rho^2} e_1\end{aligned}$$

While the others are given by

$$\begin{aligned}2. \quad Y_t - \rho Y_{t-1} &= (X_t - \rho X_{t-1}) \beta + U_t \\ \text{where } U_t &= e_t - \rho e_{t-1}, \quad (t = 2, 3, \dots, T)\end{aligned}$$

We can notice that \tilde{e}_1 has the same properties as $U_1 = e_1 - \rho e_0$

So errors in equations 1 and 2 above are uncorrelated and

homoskedasticity and the OLS method will be best, linear and unbiased.

B. SOLUTION FOR HETEROSKEDASTICITY

The way to remove heteroskedasticity is by transforming the system of equation (original equation) so that errors term have constant variance, and hence satisfy the OLS method. The procedures to remove it (Judge et al, 1982, Wonnacot and Wonnacot, 1970) are

as follows:

1. dividing both dependent and independent variables by the standard deviation of the error term for the observation;
2. applying the OLS to the transformed observations.

This procedure is known as Weighted Least Squares (WLS) because in the least square estimation each observation is weighted by the inverse of the standard deviation of the error term.

Consider the model

$$y_i = X_i \beta + e_i \quad (i = 1, 2, \dots, N), \text{ that is,}$$

$$Y = X\beta + e$$

$$E(e_t) = 0$$

$$E(e_t^2) = \sigma_t^2$$

$$E(e_t e_s) = 0 \quad (t \neq s)$$

Then the covariance matrix for vector e can be written as

$$E(ee^1) = \Omega = \begin{bmatrix} \sigma_1^2 & & \\ & \sigma_2^2 & \\ & & \sigma_N^2 \end{bmatrix} \quad \text{and} \quad \Omega^{-1} = \begin{bmatrix} \frac{1}{\sigma_1^2} & & \\ & \frac{1}{\sigma_2^2} & \\ & & \frac{1}{\sigma_N^2} \end{bmatrix}$$

If the σ_N^2 and hence Ω are known then GLS estimator for β can be calculated and is Best, Linear and Unbiased Estimator (BLUE) given by $\hat{\beta} = (X' \Omega^{-1} X)^{-1} X' \Omega^{-1} Y$, where by definition it is calculated by minimizing

$$(Y - X\beta)' \Omega^{-1} (Y - X\beta), \text{ that is,} \quad (1)$$

$$\sum_{i=1}^N \frac{(Y_i - X_i \beta)^2}{\sigma_i^2}$$

For σ_N^2 unknown (where $\Omega = \sigma^2 \Psi$) and Ψ , known as the GLS estimator, is given by

$$\hat{\beta} = (X' \Psi^{-1} X)^{-1} X' \Psi^{-1} Y \quad (2)$$

and the two estimates will give the same result because

$$(X' \Omega^{-1} X)^{-1} X' \Omega^{-1} Y = \frac{(X' \Psi^{-1} X)^{-1}}{\sigma^2} \frac{X' \Psi^{-1} Y}{\sigma^2} = (X' \Psi^{-1} X)^{-1} X' \Psi^{-1} Y, \text{ since } \Omega = \sigma^2 \Psi$$

We note that $P'P = \Omega^{-1}$ and the transformed equation can be written as

$$PY = PX\beta + Pe, \text{ or}$$

$$\tilde{Y} = \tilde{X}\beta + \tilde{e}$$

$$\text{where } \tilde{Y} = PY$$

$$\tilde{X} = PX$$

$$\tilde{e} = Pe$$

$$\hat{\beta} = (X' \Omega^{-1} X)^{-1} X' \Omega^{-1} Y$$

$$\hat{\beta} = (X' P' P X)^{-1} X' P' P Y$$

$$\hat{\beta} = (\tilde{X}' \tilde{X})^{-1} \tilde{X}' \tilde{Y}$$

and so the GLS estimator can be obtained by applying the OLS method

to the \tilde{Y}, \tilde{X} where $P = \text{diag} (\sigma_1^{-1}, \sigma_2^{-1}, \dots, \sigma_N^{-1})$ or

$$P = \begin{bmatrix} \frac{1}{\sigma_1} & & \\ & \frac{1}{\sigma_2} & \\ & & \frac{1}{\sigma_N} \end{bmatrix}$$

And the transformed observations are shown as follows:

And the transformed observations are shown as follows:

$$y_2 \begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ y_N \end{bmatrix} = \begin{bmatrix} \sigma_1^{-1} & & & & \\ & \sigma_2^{-1} & & & \\ & & \ddots & & \\ & & & \sigma_N^{-1} & \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ y_N \end{bmatrix} = \begin{bmatrix} y_1 / \sigma_1 \\ y_2 / \sigma_2 \\ \cdot \\ \cdot \\ y_N / \sigma_N \end{bmatrix}$$

$$x_2 \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ x_N \end{bmatrix} = \begin{bmatrix} \sigma_1^{-1} & & & & \\ & \sigma_2^{-1} & & & \\ & & \ddots & & \\ & & & \sigma_N^{-1} & \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ x_N \end{bmatrix} = \begin{bmatrix} x_1 / \sigma_1 \\ x_2 / \sigma_2 \\ \cdot \\ \cdot \\ x_N / \sigma_N \end{bmatrix}$$

$$e_2 \begin{bmatrix} e_1 \\ e_2 \\ \cdot \\ \cdot \\ e_N \end{bmatrix} = \begin{bmatrix} \sigma_1^{-1} & & & & \\ & \sigma_2^{-1} & & & \\ & & \ddots & & \\ & & & \sigma_N^{-1} & \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \\ \cdot \\ \cdot \\ e_N \end{bmatrix} = \begin{bmatrix} e_1 / \sigma_1 \\ e_2 / \sigma_2 \\ \cdot \\ \cdot \\ e_N / \sigma_N \end{bmatrix}$$

For the whole model can be written as $\frac{y_N}{\sigma_N} = \frac{x_N' \beta}{\sigma_N} + \frac{e_N}{\sigma_N}$

Where the variance of the transformed error term is constant, that is,

$$E(e_N^2) = E \left[\frac{e_N^2}{\sigma_N^2} \right] = \frac{1}{\sigma_N^2} E(e_N^2) = \frac{\sigma_N^2}{\sigma_N^2} = 1$$

Now because the variance of the error term is constant, the OLS method may be applied to the transformed equation by substituting PY and PX for Y and X in coefficient estimator

$$\hat{\beta} = (X'X)^{-1}X'Y, \text{ that is,}$$

$$\hat{\beta} = \left[(PX)'(PX) \right]^{-1} (PX)'(PY)$$

$$\hat{\beta} = \left[X'(P'P)X \right]^{-1} X'(P'P)Y$$

where $P'P = \text{diag} \left(\frac{1}{\sigma_1^2}, \frac{1}{\sigma_2^2}, \dots, \frac{1}{\sigma_N^2} \right)$ which is the same as Ω^{-1}

Note: Different authors give different notations for covariance matrix, that is,

Judge, G.G. et al. (1982) gives $\sigma^2_{I_T} = \sigma^2_{\Psi} = \Psi$

Pindyk, R.S. and Rubinfeld, D.L. (1981) and Johnston, J. (1972)

give $\sigma^2_{I_n} = \sigma^2_{\Omega} = \Omega$

Kmenta, J. (1971) gives $\sigma^2_{I_n} = \Omega$

Appendix

Table A.4.2

Area harvested of Paddy, Fertilizer Consumption
and Irrigated Land

		Regions							
		W.Java	C.Java	E.Java	N. Sum.	C. Sum.	S. Sum	Slwsi	Klmnt Bali
Period									
1969	(a)	1.518	1.191	1.143	352	247	188	570	421 135
	(b)	802	729	896	72	169	67	241	29 30
	(c)	63	30	75	7	12	40	1	0.12 1
1970	(a)	1.526	1.199	1.136	383	247	179	598	461 138
	(b)	802	729	896	81	174	70	242	31 33
	(c)	43	62	63	10	4	9	4	0.14 2
1971	(a)	1.577	1.221	1.151	415	246	199	603	470 151
	(b)	802	733	899	81	175	60	252	47 38
	(c)	66	60	72	14	5	3	2	0.02 3
1972	(a)	1.555	1.209	1.140	427	236	167	463	453 150
	(b)	805	745	899	81	175	67	254	48 38
	(c)	77	56	91	13	7	3	2	0.87 2
1973	(a)	1.716	1.232	1.181	436	237	185	552	511 143
	(b)	808	736	899	81	175	67	254	48 38
	(c)	114	101	110	20	12	6	7	1 6
1974	(a)	1.755	1.311	1.263	404	254	228	564	514 155
	(b)	811	739	897	96	175	67	274	50 47
	(c)	134	88	102	28	13	8	8	3 10
1975	(a)	1.756	1.258	1.262	363	248	230	630	530 129
	(b)	811	739	896	126	189	68	274	50 47
	(c)	129	96	132	18	10	11	8	2 14
1976	(a)	1.700	1.140	1.277	401	240	234	616	546 140
	(b)	816	749	913	131	190	69	279	58 51
	(c)	122	96	135	19	10	11	10	2 12
1977	(a)	1.575	1.199	1.262	396	242	239	648	554 152
	(b)	816	749	914	192	190	69	308	58 52
	(c)	152	109	191	46	14	15	11	2 19
1978	(a)	1.733	1.309	1.310	427	256	251	716	572 159
	(b)	822	749	910	196	192	86	314	65 53
	(c)	142	143	192	58	15	20	27	3 19
1979	(a)	1.708	1.248	1.338	434	258	259	703	568 166
	(b)	830	749	922	214	204	80	392	66 56
	(c)	156	144	239	65	19	34	20	2 20

(a) Area harvested of Paddy (000 ha)

(b) Irrigated Land (000 ha)

(c) Fertilizer (NPK 000 tons)

C = Central; E = East; N = North; S = South; W = West

Klmnt = Kalimantan; Sum.= Sumatra; Slwsi = Sulawesi

Source : (a) Central Bureau of Statistics

(b) Direktorat Jenderal Pertanian Tanaman Pangan

(c) Department of Public Works

Appendix

Table A.4.3

CHTWAM and CCTWAM

Variables	Coefficient estimators	
	CHTWAM	CCTWAM
Constant	1.058 (3.256)**	0.861 (9.643)**
Ln FTOP	-0.644 (-2.424)**	-1.022 (-18.545)**
F	0.646 (6.852)**	0.540 (21.365)**
IRR	0.010 (2.290)**	0.010 (15.832)**
R^2	0.671	0.718
\bar{R}^2	0.660	0.709
F	61.800	80.210
DW	1.965	1.703
D-h	0.447	1.509
RSS(R)	67.429	57.680
RSS(UR)	17.819	17.819
F (pooling test)	14.095**	11.326**

Values in parentheses are t values

RSS(R) Restricted Residual Sum of Squares

RSS(UR) Unrestricted Residual Sum of Squares

** significant at 1%

Appendix

Table A.4.4

Covariance Model

Regions	Intercept	Ln FTOP	F
Region specific coefficient for slope and intercept			
1 West Java	5.162 (15.448)**	-1.095 (-2.477)**	-0.209 (-2.964)**
2 Central Java	4.671 (14.749)**	-1.096 (-4.402)**	-0.375 (-0.529)
3 East Java	5.053 (14.876)**	-1.431 (-4.911)**	-0.407 (-0.571)
4 North Sumatra	3.992 (10.954)**	-1.458 (-3.139)**	0.645 (0.732)
5 Central Sumatra	4.586 (12.597)**	-1.784 (-3.209)**	-0.187 (-2.091)**
6 South Sumatra	5.312 (14.613)**	-2.744 (-5.841)**	-0.294 (-3.380)**
7 Sulawesi	3.675 (5.481)**	-3.581 (-3.053)**	-0.248 (-1.221)
8 Kalimantan	0.344 (1.001)	-0.449 (-0.418)	0.612 (3.018)**
9 Bali	1.696 (1.603)*	-0.544 (-0.341)	0.642 (2.779)**
R ²	0.908		
\bar{R}^2	0.883		
F	35.129 **		
DW	2.088		
D-h	-0.711		
RSS(R)	18.893		
RSS(UR)	17.819		
F (pooling test)	0.307		

Values in parentheses are t values

RSS(R) Restricted Residual Sum of Squares

RSS(UR) Unrestricted Residual Sum of Squares

* Significant at 5%

** Significant at 1%

REFERENCES

- Affif, S. and Timmer, C.P., 1971. 'Rice Policy in Indonesia', FRIS, vol.X, no.2, pp.129-159.
- Asian Development Bank, 1977.Rural Asia: Challenge and Opportunity, Praeger Special Studies, New York.
- Asian Productivity Organization, 1979. Fertilizer Distribution in Selected Asian Countries, Tokyo.
- Arnon, I., 1981. Modernization of Agriculture in Developing Countries, John Willey and Sons, Chichester.
- Balestra, P. and Nerlove, M., 1966. 'Pooling Cross-section and Time-series Data in the Estimation of a Dynamic Model: The D and for Natural Gas',Econometrica, vol.34, no.3, pp.585-612.
- Barker, R. and Hayami, Y., 1976. 'Price Support versus Input Subsidy for Food Self-sufficiency in Developing Countries', American Journal of Agricultural Economics, vol.58, no.4, pp.617-628.
- Booth, A. and Glassburner, B., 1975. 'Survey of Recent Development', BIES, vol.XI, no.1, pp.1-40.
- Booth, A. and McCawley, P.T., 1981.The Indonesian Economy During the Soeharto Era, Oxford University Press, Kuala Lumpur.
- Bridge, J.L., 1971. Applied Econometrics, North-Holland Publishing Company, Amsterdam.
- Brown, T.M., 1952. 'Habit Persistence and Lags in Consumer Behaviour', Econometrica, vol.20, no.3, pp.355-371.
- Central Bureau of Statistics, Statistical Pocket Book of Indonesia, various issues.
- Chetty, V.K., 1968. 'Pooling of Time-series and Cross-section Data',Econometrica, vol.36, no.2, pp.279-290.
- Chiang, A.C., 1974. Fundamental Methods of Mathematical Economics, 2nd.ed., McGraw-Hill Kogakusha Ltd., Tokyo.
- David, C.C., 1976. 'Fertilizer Demand in the Asian Rice Economy', FRIS, vol.XV, no.1, pp.107-123.
- David, C.C. and Barker, R., 1978. 'Modern Rice Varieties and Fertilizer Consumption' in IRRI, 1978. 'Economic Consequences of the New Rice Technology', Los Banos, Laguna, Philippines.
- Dick, H., 1979. 'Survey of Recent Development', BIES, vol.XV, no.1, pp.1-44.
- , 1982. 'Survey of Recent Development', BIES, vol.XVIII, no.1, pp.1-38.

- Dillon, J.L., 1977. The Analysis of Response in Crops and Livestock Production, 2nd.ed., Pergamon Press, Oxford.
- Ekelund, Jr., Furubotu, E.G. and Gramm, W.P. (eds.), 1972. The Evolution of Modern Demand Theory, Lexington Books, D.C. Heath and Company, Lexington, Massachusetts.
- Ekonomi dan Keuangan Indonesia, 1980, vol.XXVIII, no.3, pp.239-271.
- Evenson, R., 1974. 'The Green Revolution in Recent Development Experience', Amer. J. Agr. Econ., vol.56, pp.387-94.
- Grilliches, Z., 1958. 'The Demand for Fertilizer: An Econometric Interpretation of a Technical Change', Journal of Farm Economics, vol.40, no.3, pp.591-606.
- Hayami, Y., 1964. 'Demand for Fertilizer in the Course of Japanese Agricultural Development', Journal of Farm Economics, vol.46, no.4, pp.766-779.
- Heady, E.O. and Yeh, M.H., 1959. 'National and Regional Demand Function for Fertilizer', Journal of Farm Economics, vol.41, pp.332-348.
- Hsu, R.C., 1972. 'The Demand for Fertilizer in a Developing Country: The Case of Taiwan', Economic Development and Cultural Change, vol.20, no.2, pp.299-309.
- Houthakker, H.S. and Taylor, L.D., 1966. Consumer Demand in the United States, 1929-1970, Harvard University Press, Cambridge, Massachusetts.
- Houthakker, H.S., 1965. 'New Evidence on Demand Elasticities', Econometrica, vol.33, no.2, pp.277-88.
- Intrilligator, M.D., 1978. Econometric Models, Techniques, and Applications, Prentice-hall, Inc., Englewood Cliffs, N.Y.
- IRRI, 1978. Economic Consequences of the New Rice Technology, Los Banos, Laguna, Philippines.
- Ishikawa, S., 1967. Economic Development in Asian Perspective, Kinokuniya Bookstore Co. Ltd., Tokyo, Japan.
- Johnston, J., 1972. Econometric Methods, 2nd. ed., McGraw-Hill Kogakusha Ltd., Tokyo.
- Judge, G.G., Hill, R.C, Griffiths, W.E., Lutkepohl, H. and Tsoung-Chao Lee, 1982. Introduction to the Theory and Practice of Econometrics, John Willey and Sons.
- Klein, L.R., 1962. An Introduction to Econometrics, Prentice-hall, Inc., Englewood Cliff, New York.
- Kmenta, J., 1971. Elements of Econometrics, McMillan Publishing Co., Inc., New York.

- Kolff, J., 1971. 'The Distribution of Fertilizer', BIES, vol.VII, no.1, pp.56-77.
- Kooyman, M.A., 1976. Dummy Variables in Econometrics, Tilburg University Press, The Netherlands.
- Koutsoyiannis, A., 1977. Theory of Econometrics, The McMillan Press Ltd., London.
- Krishna, R., 1967. 'Agricultural Price Policy and Economic Development', in Southworth and Johnston (eds.), 1967. Agricultural Development and Economic Growth, Cornell University Press, Ithaca, New York.
- Maddala, G.S., 1971. 'The Likelihood Approach to Pooling Cross-section and Time-series Data', Econometrica, vol.39, no.6, pp.939-953.
- Maddala, G.S., 1977. Econometrics, McGraw-Hill Kogakusha, Ltd., Tokyo.
- McCawley, P.T., 1976. 'Survey of Recent Development', BIES, vol.XII, no.1, pp.1-40.
- McCawley, P.T. and Manning, C., 1976. 'Survey of Recent Development', BIES, vol.XII, no.3, pp.1-49.
- McCawley, P.T., 1983. 'Survey of Recent Development', BIES, vol.XIX, no.1, pp.1-31.
- Mears, L.A. and Moelyono, S., 1981. Food Policy, in Booth, A. and McCawley, P., 1981. 'The Indonesian Economy During the Soeharto Era, Oxford University Press, Kuala Lumpur.
- Mears, L.A., 1981. The New Rice Economy of Indonesia, Gadjah Mada University Press, Indonesia.
- Mubyarto, 1970. Rice Price and Production Policies in Indonesia, in Agricultural Revolution in Southeast Asia, Report of SEADAG, Rural Development Seminar Meeting, Honolulu, 1969, vol.I.
- Mudahar, M.S., 1980. Needed Information and Economic Analysis for Fertilizer Policy Formulation, A/D/C, no.24, pp.1-28, New York.
- Mulyono, B., 1979. 'Indonesia' report in APO, 1979, Fertilizer Distribution in Selected Countries, Tokyo.
- Mundlak, Y., 1963. Estimation of Production and Behavioral Functions from a Combination of Cross-section and Time-series Data, in Christ and others (ed.), 1963. Measurement in Economics, Stanford University Press, Stanford California.
- Murphy, J.L., 1973. Introductory Econometrics, Richard D. Irwin Inc., Homewood, Illinois.

- Nguyen Trung Truc, 1975. A Study of Rice Intensification Programs in Indonesia 1965-73, Unpublished Thesis, Flinders University of South Australia.
- Nerlove, M., 1971. 'Further Evidence on the Estimation of Dynamic Relation from a Time-series of Cross-sections', Econometrica, vol.39, no.2, pp.359-382.
- Palacpac, A.C., 1982. 'World Rice Statistics', the IRRI, Department of Agricultural Economics, Los Banos, Philippines.
- Parikh, A., 1965. 'Demand for Nitrogeous Fertilizers: An Econometric Study', Indian Journal of Agricultural Economics, vol.XX, no.3, pp.1-19.
- Parikh, A., 1966. 'Consumption of Nitrogeous Fertilizers: A Continuous Cross-section Study and Covariance Analysis', Indian Economic Journal, vol.XIV, no.3, pp.259-274.
- Parish, R. and McLaren, K., April, 1982. 'Relative Cost-Effectiveness of Input and Output Subsidies', The Australian Journal of Agricultural Economics, vol.26, no.1, pp.1-13.
- Pindyck, R.S., and Rubinfeld, D.L., 1981, Econometric Models and Economic Forecasts, McGraw-Hill, Inc.
- Pitt, M.M., 1981. Estimating Farm-level Fertilizer Demand in Java with respect to M a-Production Function, pp.1-18, mimeo.
- Prais, S.J. and Houthakker, H.S., 1955. The Analysis of Family Budgets, Cambridge University Press, Cambridge.
- Rachman, A. and Montgomery, R., 1980, 'Asian Fertilizer Demand Reconsidered: An Application to Java and Bali' in Ekonomi dan Keuangan Indonesia, vol.XXVIII, no.3, pp.239-271.
- Republik Indonesia, Departemen Keuangan. Nota Keuangan, various issues.
- Republik Indonesia, Departemen Pertanian, Direktorat Bina Sarana Usaha Tanaman Pangan. Kumpulan Data Pupuk Indonesia, various issues.
- Republik Indonesia, Departemen PUTL, Data sheets.
- Rice, R.C. and Lim, D., 1976. 'Survey of Recent Development', BIES, vol.XII, no.2, pp.1-29.
- Schultz, H., 1938. The Theory and Measurement of Demand, The University of Chicago Press, Illinois.

- Sidhu, S. and Baanante, C.A., 1979. 'Farm-level Fertilizer Demand for Mexican Wheat Varieties in the Indian Punjab', American Journal of Agricultural Economics, vol.61, pp.455-462.
- Singh, B. and Ullah, A., 1976. 'The Consumption Function: The Permanent Income versus the Habit Persistence Hypothesis' The Review of Economics and Statistics, vol.58, no.1, pp.96-103.
- Slayton, T.M. and Exawirya, I.G.N., 1978. 'The Fertilizer Situation', BIES, vol.XIV, no.2, pp.70-84.
- Stone, R., Rowe, D.A., Corlett, W.J., Hurstfield, R. and Potter, M., 1954. The Measurement of Consumers' Expenditure and Behaviour in the United Kingdom 1920-38, Cambridge University Press, Cambridge.
- Stone, R., 1954. 'Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand', The Economic Journal, vol.64, pp.511-527.
- Timmer, C.P., 1974. 'The Demand for Fertilizer in Developing Countries', FRIS, vol.XIII, no.3, pp.197-224.
- Timmer, C.P., 1975. 'The Political Economy of Rice in Asia: Indonesia', FRIS, vol.XIV, no.3, pp.195-231.
- Timmer, C.P., 1976. 'Fertilizer and Food Policy in LDCs', Food Policy, vol.1, no.2, pp.143-154.
- Tomek, W.G. and Robinson, K.L., 1972. Agricultural Product Price, Cornell University Press, Ithaca, Cornell.
- Uexkull, H.R. von, 1970. 'Significance of the Use of Chemical Fertilizer in Modern Agriculture with Special Reference to the Problems of the Less Developing Countries', Food and Fertilizer, no.3, pp.1-13.
- Uexkull, H.R. von, 1975. 'Recent Fertilizer Problems in Asia', Food and Fertilizer, no.59, pp. 1-49.
- Warr, G., 1980. 'Survey of Recent Development', BIES, vol.XVI, no.3.
- Wold and Jureen, 1953. Demand Analysis: A Study of Econometrics, John Willey and Sons, Inc., New York.
- Wonnacott, R.J. and Wonnacott, T.H., 1970. Econometrics, John Willey and Sons, Inc., New York.
- World Bank Report, 1978. Indonesia: A Review of the Support Services for Food Crop Production.
- Young Kun Shim, 1980. 'Support Policies for Future Development of Fertilizer use in Asia', Food and Fertilizer, no.142, pp.1-15.